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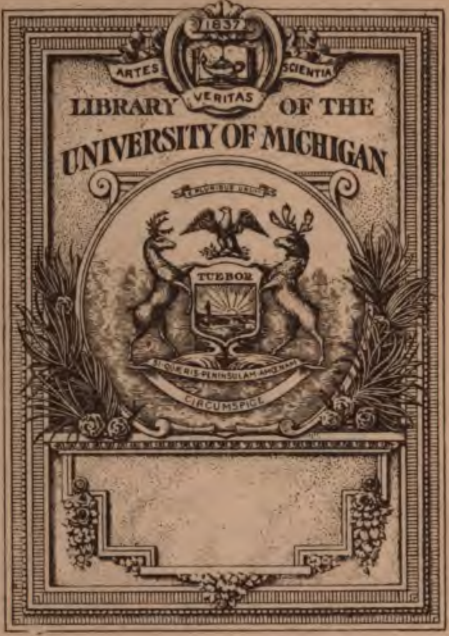

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to the required angle. We then proceeded to prepare a somewhat elaborate work on Isometrical Drawing, in which, we have the assurance to believe, we were able to extend and simplify the principles of the art; but when the drawings were all made, and the book was ready for the press, it occurred to us that a still more easy system of industrial drawing, more nearly approaching linear perspective in appearance, and equally practical with isometrical drawing, might be invented; and the result has been the system of *Cabinet Perspective*, which is now offered to the public in the Second, Third, and Fourth Numbers of the "Industrial Drawing Series." If we are not greatly mistaken, this system of Cabinet Perspective, which is so very simple in plan, and so easy of execution as to render its more valuable portions capable of being understood and practiced by the children in our primary schools, will give to the subject of *industrial* drawing, in its application to the representation of solids of every variety of form, a value hitherto unknown.

While we regard it, however, as better for *most* industrial drawings, especially for school purposes, than Isometrical Perspective, yet the latter has some very valuable adaptations; and, as it can be easily applied by those who understand Cabinet Perspective, we have given an exposition of its principles in the Appendix to the present volume.

A peculiarity in the plan of the system now offered to the public consists in placing the drawings which are to be imitated, or which are to serve as models for suggesting original designs, on paper printed with fine lines one eighth of an inch apart, and in furnishing the pupil with similarly printed red or pink-lined paper on which to make his drawings. These lines cross each other at right angles, vertically and horizontally. Any draughtsman will see at a glance with what facility and accuracy a figure may be copied from the Drawing-Book on paper thus prepared; how readily it may be enlarged to any extent, or diminished, in true proportion; and how easy it is, with the aid of such paper, to design new patterns and models, and draw them in perfect symmetry in all their parts. Draughtsmen are often obliged to rule paper in a similar manner, for their own use, in making intricate patterns; and it is perfectly evident that the vast variety of decorative designs which we find among the remains of Egyptian, Grecian, Roman, Byzantine, and Arabian art, was formed upon paper, or papyrus, ruled by pencil in this identical manner, although not on the scale which we have used. Indeed, these ancient patterns could not possibly have been executed with the accuracy which they exhibit without such aid. They show the accurate direction of the diagonal and other oblique lines, which are so easily formed upon such ruling. For all purposes of illustrating industrial art, the two kinds of ruled drawing-paper—both Cabinet and Isometrical—will be found invaluable. Their varied applications will be seen throughout the Industrial Drawing Series.

In Drawing-Book No. I. we have taken up, in an elementary manner, the subject of Decorative Design—both on account of its being well adapted to elementary practice in drawing, and because of its importance in nearly all departments of industrial art.

In our drawing-lessons under this head, we have aimed, in the first place, to furnish a variety of such copies as are most suitable for elementary exercises in training the hand and the eye, while at the same time they shall be adapted to cultivate a correct taste for that which combines harmony of design with grace and beauty of form. Hence, instead of thinking it desirable that we should originate all of our figures for the drawing exercises, we have selected them, in great part, from the best examples of the decorative art of all ages, being parts, or wholes, of patterns which have stood the test of time, the only true standard of taste. By this course we are not only able to give a very great variety of excellent patterns for imitation, and for suggestion in designing, but we are also enabled to impart to the pupil some general knowledge of those principles of form and proportion which govern all true art decoration; and in the introductory articles we have given brief sketches of the growth and development of these principles in different nations and in different periods of civilization. Should the Series be carried so far as we now anticipate, we hope, in higher numbers, to greatly enlarge upon the designs here given; to show the application of industrial drawing to various specific forms of industry; and also to illustrate the Harmonies of Color, as applied to decorative art.

But we would, furthermore, call special attention to the new method of representing objects, called CABINET PERSPECTIVE, as illustrated in Drawing-Books Numbers II., III., and IV., and embracing both plane and curvilinear solids in almost every variety of form and position. This kind of perspective, when carried out by the use of the ruled drawing-paper, enables us to construct all kinds of *working drawings* for artisans—drawings which, instead of giving a geometrical representation of but *one side* of a rectilinear object, present in one view *three sides*, at the same time avoiding the appearance of distortion, and giving, with perfect accuracy, the same as Isometrical Perspective, the dimensions of the objects represented, according to whatever scale the draughtsman may adopt. Moreover, the principles of the system are so simple that a child can understand them; while any one who can draw straight lines by the aid of a ruler, and curved lines by the aid of a pair of compasses, can apply them.

As indicating something of the scope of the system, as applied to solids, we have represented, under this head, within the narrow limits which we have assigned to ourselves, such objects as cabinet frame-works of various forms; tables; cubical, hexagonal, octagonal, and other blocks, either entire, [illegible] ariously cut and divided; crosses; star figures; boxes;

English bond and Flemish bond—forms of brick-laying; pillars and their mouldings; pyramids, obelisks, etc.; post and board, post and rail, and picket fences; various forms of the solid Grecian fret, and other architectural ornaments; framework of bridges; cylinders, solid or hollow, entire, or variously cut and divided, and in both horizontal and vertical positions; arches, both pointed and semicircular; braces and brackets, both plain and curvilinear; solid quarterfoils and trefoils; wheels, in sections, and entire—with crown-wheel, ratchet-wheel, chain-pulley wheel, etc.; windlass; vertical and beveled tubs, both circular and octagonal; ground-plans and elevations of buildings; tenon and mortise work; scarf-jointing of timbers; stairways; platforms; ellipses; rings, etc., etc., and all drawn to definite dimensions, while the measurements are indicated by the drawing-paper itself. By this system the study of drawing, in its application to the industrial arts, is rendered one of the exact sciences, wholly mechanical in execution, and as accurate in its delineations as geometry itself. We have here presented only an *elementary* exposition of the system, designed for school purposes; but the system itself is so simple, that, with the helps here given, the intelligent teacher and pupil will find little difficulty in carrying out the application of its principles to any extent which may be desired.

For several of the rules and principles of Ornamental Art, and also for many of the designs in Drawing-Book No. I., we are indebted to the "*Grammar of Ornament*," by Owen Jones. It may, perhaps, be thought that it was not especially desirable to preface an Elementary Drawing Series with a statement of the general principles of Art Decoration, and an account of the Leading Schools or Periods of Art, for the reason that such information will seldom be appreciated by beginners in drawing. But to teachers at least—and not merely teachers of drawing—we may hope that these introductory pages will be of some value; and if they shall serve merely to enlarge the ideas of both teachers and pupils as to the magnitude and importance of the subject of art representation, they will thereby have done a good service to the cause of education.

We would take this occasion to impress upon educators, and those who have the management of our Public Schools, the extreme desirability that all the school instruction in elementary industrial drawing shall be given by the ordinary teachers; and that professional drawing-masters shall be employed, if at all, only in the training of the teachers themselves—in a general superintendence of the whole subject of art instruction in all the schools of a city, or county, or even larger district—or in giving instruction to advanced students in the higher Schools of Design. The teachers in our Public Schools are competent to give all the instruction required by their classes in industrial drawing; and care should be taken that pupils do not get the idea that they are required to do something which their teachers themselves can not do.

MARCIUS WILLSON.

VINELAND, N. J., *June* 5, 1873.

PART I.

PRINCIPLES AND PRACTICE

OF

ORNAMENTAL ART.

I.

INTRODUCTORY.

We desire to offer to the public a few introductory remarks on Ornamental Art, a subject which we have endeavored to illustrate, in a very elementary manner, in the first book of our Industrial Drawing Series.

We are aware that those who have given the subject but little attention entertain very erroneous ideas of the importance and value of a knowledge of the principles and practice of decoration, as applied to the products of human industry. A very little reflection, however, must convince the most utilitarian, that, in an advanced stage of society, decoration enters so fully into all works of art as to constitute, in perhaps a majority of cases, the greater part of their market value. We see the principle illustrated in the importance that is attached to surface ornamentation in the manufacture of carpets, and oil-cloths, and matting, and wall-paper, and curtains; in printed cloths, and other articles designed for dress; in crochét and tapestry work; in the elegant forms required for vases, and all crockery and earthenware; alike in the fine sculpture of the most delicate ornaments and the chiseling of stone for public and private dwellings; in all mouldings of wood, and iron, and other ornamental work in architecture; and it is found to enter into all plans and patterns of utensils and tools, and into all objects of art which may be deemed capable of improvement by giving to them increased beauty of form and proportion. Indeed, all the vast variety of form and color which we observe in the works of man, beyond the requirements of the most barren utility, is, simply, ornamentation. Beginning with the savage, with whom ornament precedes dress, it has been the study of man in all ages not only to make art beautiful, but to improve upon nature also. The subject is thus seen to embrace all that, in industrial art, marks the advance of civilization, and decoration may be taken as a true exponent, at every stage of its development, of the progress of society. [illegible] the useful arts and the elegancies of life are ever found to grow together.

If decoration, therefore, [illegible] enters so largely into the daily life of civilized society as to be every where recognized, [illegible] admired, and practiced, it would seem not only appropriate, but very desirable, that its elementary principles should early find a place at the beginning of every system of public instruction—and, where they properly belong, in the study and practice of *Industrial Drawing.*

England is so decidedly a manufacturing country, that art education has there long been deemed a national necessity; and it is not only thought important that the manufacturer should understand the laws of beauty, and the principles of design, in order that his products may command a ready market, but that the artisan also—the mere workman in art—shall possess something of the skill which comes from educated taste. More than thirty years ago a British Association for the Advancement of Art, composed of the chief nobility, capitalists, bankers, merchants, and manufacturers of the kingdom, sent out the declaration and appeal, that, without a pre-eminence in the arts of design, British manufacturers could not retain, and must eventually lose, their superiority in foreign markets. But the English government remained, for years, deaf to the warning; and at the great Exhibition of the Industry of all Nations, held in London in 1851, England found herself almost at the bottom of the list in respect to excellence of design in her art manufactures—only the United States, among the great nations, being below her. This discovery aroused the English government to a realizing sense of the vast importance of the highest and most widely diffused art education for a manufacturing people; and the result was the speedy establishment of an Educational Department of Science and Art, from which Schools of Design have radiated all over the

In these and other schools, even ten years ago,

and students were in training as future teachers of art, and fifteen thousand pupils were receiving an art education; while in the parish and public schools more than fifty thousand children of the laboring and poorer classes were receiving more or less instruction in elementary drawing. In the higher art schools the pupils are taught not only the practice, but the principles also, of ornamental design; they are shown how all assemblages of ornamental forms are arranged in geometrical proportions: how curves must flow, the one into the other, without break or interruption; and they are taught to analyze and interpret the characteristic ideas of various styles and schools of art, such as we have given a brief synopsis of under the heading of "Ornamental Art among Different Nations, and in Different Periods of Civilization." The wisdom of England's course was very apparent at the Paris Exhibition of 1867, when it was seen that England had risen, in a period of sixteen years, from a position among the lowest, to one foremost among the nations in art manufactures—showing the effects of the art education which she had so sedulously fostered. As humiliating as it is to our national pride, truth compels us to add, in the language of another—"The United States still held her place at the foot of the column." In England, in 1870, besides the attention given to drawing in the public schools and in evening classes, there were more than twenty thousand students in the art schools, and more than thirty thousand in the schools of industrial science; and it is reported that, in the two following years, the numbers in both were doubled.

A notable illustration of the commercial value of the beautiful in art is afforded in the colossal growth of the earthenware trade in England, which started into sudden notoriety when the young sculptor, Flaxman, was employed to model, from fine specimens of antique sculpture, those beautiful urns, vases, goblets, and other articles for table service and other domestic uses, long known as the *Wedgewood* ware. The clay pits of Staffordshire were turned into gold mines, and made a source of national wealth, when the proprietors employed good artists to draw designs and select antique models for their workmen; and it has been stated by competent judges that, through the establishment of Art Museums and Schools of Design, and the influences exerted thereby, combined with popular instruction in industrial drawing, England has added fifty per cent. to the value of her manufactured products during the past twenty-five years. And, turning to the Continent, we find it is the art instruction imparted in the schools and in the manufactories of France, showing how colors are distributed, balanced, and harmonized, both in nature and in art, that has given to the silk fabrics of Lyons, the *Gobelin* tapestry, and to other national products, their world-wide renown for harmony and beauty. In France, education in science and art is now placed by law in the same rank as classical education.

In our own country public attention is now being turned, in a very marked manner, to the subject of art education: and in Massachusetts, after the subject had been agitated by the leading manufacturers and merchants, laws have been passed securing to pupils instruction in elementary drawing in every public school in the state; making "industrial or mechanical drawing" free to persons over fifteen years of age either in day or evening classes, in cities and towns that have a population above ten thousand; and a State Director of Art Education has been appointed to supervise the system; but, generally, throughout our schools, what little imperfect instruction in art has been given has thus far been confined, mostly, to the mere copying of pictures—and, where it has gone beyond that, to the education of *artists* rather than of artisans. It is seldom addressed, as it should be, to the principles and practice of ornamental design; to the harmonies of color, form, and proportion; and to such representations of objects as are most needed by workingmen in the arts. This kind of art knowledge and practice would not only be of interest, but of utility to all; and the mechanic who could make the best use of it in his line of business would ever have a decided advantage over all competitors. An incident bearing upon this point is related by the State Director of Art Education for Massachusetts, to the effect that, "some years ago a class of thirteen young men spent all their leisure time in studying drawing, and that now, at the time of writing, every one of them holds some important position, either as manufacturer or designer." And if we would build up our manufactories on a broad scale, so as to bring their products into successful competition with those of England and France, we must not rely upon a few imported draughtsmen and designers, and vainly hope that uneducated artisans will work out foreign patterns with taste and beauty; but we must lay the foundations of art superiority broad and deep in the art education of all mechanics, and in the educated tastes of the people. Then draughtsmen and designers will spring up wherever needed; and the workmen in our shops and manufactories, understanding the principles of their several trades and professions, will be all the more skilled in the practice of them. And what we need for this is not merely a few Schools of Design, and Art Museums, valuable as these may be, but the introduction of the principles of design, and the practice of art representation, into the education of the people at large.

But here the practical question is suggested: *How* shall we introduce *Industrial Drawing* into our schools, so that all our youth may profit by it, when so many other important studies are crowding for admission, and our teachers have already quite as much as they can attend to? We reply, Alternate it with the writing-lessons; and experience fully proves that better penmanship will be attained thereby, while the drawing, and the knowledge which it introduces, will be a positive gain, without any attendant loss. Long ago, said that veteran educator, Horace Mann, "I believe a child will learn both to draw and write sooner, and with more ease, than he will learn writing alone."

In conclusion, we commend this whole subject of *Industrial Art Education* as worthy the earnest consideration, not only of all educators, but also of all mechanics and artisans, and of all who appreciate the vast proportions which our manufacturing interests are destined to assume in the not far distant future.

II.

GENERAL PRINCIPLES OF ORNAMENTAL ART.

There are two kinds of beauty in Ornamental Art: the one is the beauty of design and execution, arising from the exhibition of skill on the part of the designer and artisan; the other is the beauty of character, which arises from the expression of thought or soul in the object itself. The beauty of the former is fully realized only by those who are proficients in the art, and ceases to be felt when the art has made a farther progress. The beauty of the latter, inasmuch as it appeals to the sensibilities of all, is universally felt, although in a different degree by different individuals, and is by far the most lasting; and the former should ever be subordinate to it. The difference between the two kinds of beauty is best illustrated in architecture, of which ornament is the very soul and spirit. All that utility requires in the structure, skill may accomplish by the aid of mere rule and compass; but the ornamentation shows how far the architect was, at the same time, an artist.

Proposition I.—A Cardinal Principle.

All decoration should exhibit a fitness or propriety of things, just proportions, and harmony of design.

All ornaments should harmonize in expression with the expression designed to be given to the objects to which they are affixed. Thus there are art objects of convenience and use, of sublimity, of splendor, of magnificence, of gayety, of delicacy, of melancholy, etc.; and the ornaments affixed to each should fully harmonize with its character. Any fabric to be ornamented should, in the first place, be suited to its proposed uses; and then, in strict keeping with the main design, must be the decoration which adorns its surface. Hence, to cover an oil-cloth, or a chair cushion, with drawings of cubical blocks set on edge, as we have seen, is an outrage upon the uses to which either is to be put; and alike improper is it to load a carpet, designed for the tread of feet, with vases filled with fruits, and to cover it thick with garlands of flowers. It is only in the richest velvet carpets, elastic to the tread, and where the flowers are partially lost in the profusion of herbage, that such excessive adornment may be deemed not inappropriate. As is well known, the Greek orders of architecture have manifest differences of character or expression. Thus the heavy Tuscan is distinguished by its severity; the manly Doric by its simplicity, purity, and grandeur; the Ionic by its grace and elegance; the Corinthian by its lightness, delicacy, and gayety; and the Composite by its profusion and luxury; while the ornaments of the several orders fully harmonize with them in expression. Thus every product of art has some character of its own, and good taste demands that there shall be a correspondence in the decoration given to it. A degree of ornamentation that would be becoming in one object, would be insipid or mean in another;—as what would be in good taste, and beautiful, in the robes of a queen, would be inappropriate in the dress of a plain lady, and tawdry in that of a peasant girl. And although wreaths of flowers may alike deck the tomb and adorn the festive hall, yet the variety and profusion suited to the latter would not comport with the subdued feeling which is in unison with the former; and the true artist will at once discern the difference. The vase upon a tomb will not bear the variety of contour that may be given to a goblet; nor should the latter have the uniformity of moulding characteristic of a funeral urn.

PROPOSITION II.—OF ANGULAR AND WINDING FORMS.

Angular forms denote harshness, maturity, strength, and vigor. Winding forms, on the contrary, are expressive of infancy, weakness, tenderness, and delicacy, as also of ease, grace, beauty, luxury, and freedom from force and restraint.

As in all objects of taste the lightest forms consistent with the required strength are considered the most beautiful, so in all articles in which much strength is required angular forms are generally adopted, because they require a less amount of material than curvilinear forms. Hence angular forms—as of squares, lozenges, etc.—are not only best suited to such articles of furniture as chairs, tables, desks, stands, etc., but also to oil-cloths, matting, plain carpets, etc., because we associate with these latter articles much tread of feet and daily use; and yet it is equally apparent that these angular forms would not be appropriate for carpets of luxurious ease, for flowing robes, curtains, etc. In architecture we expect direct and angular lines, because they give the impression of stability and strength; and architectural ornaments are beautiful only as they are in harmony with the general character of the structure to which they are affixed. An angular vase, designed for holding flowers, would be exceedingly inappropriate; while, on the contrary, to make the sides of a house, or of a pyramid, curvilinear, would none the less violate our ideas of fitness and propriety. The *weeping* willow, as it is appropriately named, is adapted to mournful occasions, because it bends and droops like one in affliction; while the sturdy oak, on the contrary, of angular outlines, is representative of firmness and strength. It may break, but can not bend.

PROPOSITION III.—OF FIRM AND UNBROKEN, AND FINE AND FAINT LINES.

Firm and unbroken lines are expressive of strength and boldness, with some degree of harshness.

Fine and faint lines are indicative of smoothness, fineness, delicacy, and ease.

When the forms of *objects* are used to ornament articles of taste or utility, they should be drawn in keeping with the character of the objects themselves. Thus the visual line of a column, or of a pyramid, should be bold and unbroken, unless modified by distance of view; while the winding outlines of the tendrils of a vine, of a wreath, of a festoon, should be exceedingly *delicate*, as we say—our very language conforming to our ideas of the fitness of things. But see Proposition XI.

PROPOSITION IV.—OF CONSTRUCTION AND DECORATION.

Construction should be decorated; but decoration should never be purposely constructed.

In the weaving of lace, muslin, and other fabrics of one color, in a variety of suitable patterns, and in the similar braiding of mats, baskets, etc., the construction itself is, appropriately, decorated. So may any construction — as a building, a robe, an article of furniture, etc.—be decorated in the making of it; but to construct or plan a decoration without regard to the application or use that is to be made of it, and as if it might serve a variety of purposes, is a violation of the principles of true art. It is, therefore, the correct principle, to make the construction itself ornamental, rather than to depend upon applied ornament. Hence the veneering of the fronts of brick or wooden buildings with marble, or articles of wooden furniture with thin layers of richer wood, is a sham that gives us a feeling of disappointment when the cheat is known. So the painting or graining of wood is far less satisfactory, as a decorative agent, than the bringing out and preservation of the natural grain by a suitable varnish. Artistic arrangements of American woods properly prepared would furnish a wonderful variety, in pattern and coloring, for decorative purposes, and in far better taste than most of the surface decoration that is purposely *constructed.*

Every object of art production is supposed to be constructed with some definite aim, and to be designed to subserve some purpose of utility; or, if it be merely ornamental, it is still designed to aid in giving the true and proper expression to that object to which it is affixed. In either case, the style, character, and expression of the ornamental are to be considered as the accessories, and to be governed wholly by the character of the object of which they are the appendages. A carpet, a dress, a curtain, or a chair, etc., should be ornamented with reference to the circumstances and occasions of its uses; and, evidently, it must vary in decoration according as it may be designed for a cottage or for a palace. So mere ornaments, as rings, bracelets, brooches, etc., should be adapted to the character, personal appearance, and position in society of the wearer; for, not all beautiful things are becoming to all places, or to all persons. The proprieties of life have a very wide range of application. See *Proverbs* xi., 22.

PROPOSITION V.—OF GENERAL FORMS.

True beauty of form is produced by lines growing out of one another in gradual undulations, and supported by one another. There are no excrescences; and nothing could be removed and leave the design equally good or better.

These principles are best illustrated in the several orders of Grecian architecture, from no one of which could any portion be taken away without leaving the general form defective; and certainly no part could be enlarged without giving to it the appearance of an unseemly excrescence.

PROPOSITION VI.—OF GEOMETRICAL CONSTRUCTION.

All surface ornamentation should be based upon a geometrical construction.

Whatever the pattern of the ornament, it should be such that it can be traced back to a geometrical basis; and no ornament can be properly designed without such aid as a groundwork. Especially is this the case in woven fabrics, which are necessarily constructed on a geometrical plan.

As in the infancy of art uniformity of design was most valued, as evincing the skill of the artist; and as what children most admire, and, in their little attempts at art, first try to execute, is uniformity and regularity, so elementary drawing should begin with those simple geometrical patterns which are the groundwork of all artistic ornamentation.

Patterns in which the geometrical arrangement is at once apparent, owing to the uniformity or regularity of the details, owe the first impression of beauty which they give us to their expression of design on the part of the artist; and the more intricate the pattern, and the greater the number of its parts, while it still preserves its uniformity, the higher, in the estimation of educated taste, is its degree of beauty; only the number of parts must not be so great as to produce confusion, and thus obscure the expression of design. Where, however, a confused intricacy of detail at first seems to prevail, nothing is more delightful than to find order gradually emerging out of chaos, and a consistent plan pervading the whole. When there is added to a beautiful design intricacy and variety of detail amid uniformity, there is only needed elegance and embellishment in the workmanship to constitute the highest degree of ornamental art.

PROPOSITION VII.—OF METHODS OF SURFACE DECORATION.

The general forms of the desired ornamentation having been first drawn on some geometrical basis, consistent with the character of the object to be ornamented, these forms should then be subdivided and ornamented by general lines; the intermediate spaces may then be filled in; and the subdivision may be continued to any extent required, and until the details can be appreciated only by close inspection.

This method of designing is adapted no less to the sometimes elaborate patterns of embroidered robes and tapestry work, than to the more obvious geometrical arrangements of squares, and parallelograms, and lozenges, and circles, that are often seen in oil-cloths and carpeting. The great secret of success, even in the most complicated ornamentation, is the production of a broad general effect by the repetition of a few simple elements. "Variety should rather be sought in the arrangement of the several portions of a design, than in the multiplicity of varied forms."

In the wall or floor ornamentation of dwellings, an important principle to be observed is the use of modest tints as a back-ground, against which the furniture can be displayed to advantage, and a due subordination to the uses to which the room is to be applied—as, for example, whether it is to express the brightness, cheerfulness, and welcome of a reception-room, or the tranquillity of studious ease which is adapted to the library. If to the walls be given high colors, relief and roundness of ornamentation, and shade and shadow, instead of flat neutral tints of one or two colors, the walls are thereby apparently thrust forward, the room is made to appear smaller than it is, and the furniture is dwarfed, and its natural effect destroyed. So, large patterns in the carpet of a small room produce a like damaging effect upon both room and furniture, and destroy that feeling of satisfied repose which is ever attendant upon true art. Vertical patterns on the walls, such as columns, stripes, etc., make the walls appear higher, while horizontal lines and patterns lower the ceiling.

Proposition VIII.—Of Proportion in Ornamentation.

As in every perfect work of Architecture a true proportion will be found to reign between all the members which compose it, so throughout the Decorative Arts every assemblage of forms should be arranged on certain definite proportions; the whole and each particular member should be a multiple of some simple unit.

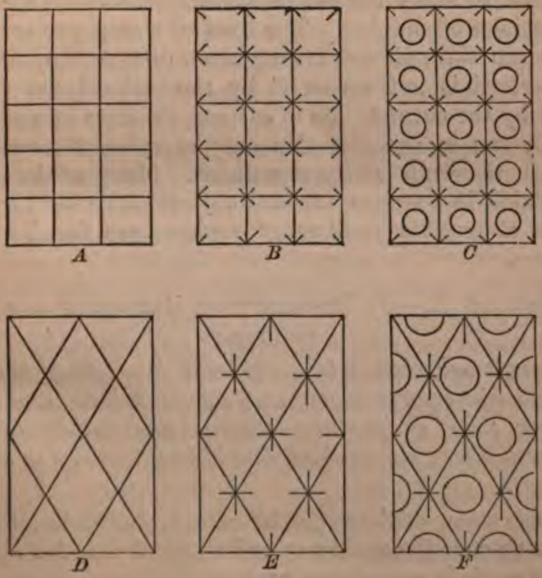
Thus the height of the Doric column was equal to six times the diameter of the lower end of the shaft; the diameter of the upper end of the shaft was three fourths of the diameter of the lower end; and the architrave, frieze, and cornice, and all other parts, had certain definite proportions. In the other orders the proportions were different; but in each the several parts were in just proportion the one to the other, and to the whole. Nor were these proportions arbitrary; for they were such as were best adapted to give expression to the character of the order; and in no one of these orders could any important part be materially changed in its proportions without doing violence to that harmony of design which characterized the entire structure.

In the infancy of Decorative Art the proportions were of the most simple kind, in accordance with the natural order of development. It is the same with the growth of art in individuals. Thus as soon as a child can draw a square, its first effort is to divide it into four squares, and then into a greater number; then to draw and subdivide parallelograms; then out of the squares to form lozenge-shaped figures, etc., and so on, as taste and skill are developed. As art advances, those proportions will be deemed the most beautiful which the uneducated eye does not readily detect.

Proposition IX.—Of Harmony and Contrast.

Where great variety of form is introduced, harmony consists in the proper balancing and contrast of the straight, the inclined, and the curved.

Whether we confine our attention to structural arrangement of edifices, or to decoration of surfaces, there can be no perfect composition in which any one of the three primary forms is wanting. In the Greek temple the straight, the angular or inclined, and the curved, are in most perfect relation to one another. In the best examples of Gothic architecture every tendency of lines to run vertically or horizontally is immediately counteracted by the oblique or the curved. Thus the capping of the buttress is exactly what is required to counteract the upward tendency of the



straight lines; so the gable contrasts admirably with the curved window-head and its perpendicular mullions.

In surface decoration any arrangement of forms, as at A, consisting only of straight lines, is monotonous, and affords but little pleasure. By introducing lines which tend to carry the eye toward the angles, as at B, the monotony is broken, and the improvement is very apparent. Then add lines giving a circular tendency, as at C, and the eye reposes itself within the outlines of the figure, and the harmony is complete. In this case the square is the leading form or tonic; the oblique and curved forms are subordinate.

An effect similar to A, but an improvement upon it, is produced by the lozenge composition, as at D. Add the lines as at E, and the tendency to follow the oblique direction is corrected; but interpose the circles, as at F, and the eye at once feels that repose which is the result of perfect harmony in the combination.

It is owing to a neglect of the principle here stated that there are so many failures in wall-paper, carpets, oil-cloths, and articles of clothing. The lines of wall-paper very generally run through the ceiling most disagreeably, because the vertical is not corrected by the inclined, nor the inclined by the curved. So of carpets, the lines of which frequently run in one direction only, carrying the eye right through the walls of the apartment. Many of the checks and plaids in common use are objectionable for the same reason, although a great relief is sometimes found in their coloring.

PROPOSITION X.—OF DISTRIBUTION, RADIATION, AND CONTINUITY.

In surface decoration by curvilinear forms, all lines should be harmoniously distributed, and should radiate from a parrent stem; and all junctions of curved lines with curved, and of curved lines with straight, should be tangential to one another.

This is a law of the vegetable world, as seen in all plants that have curvilinear forms; and Oriental practice in ornamental art is in accordance with it.

PROPOSITION XI. — OF CONVENTIONAL REPRESENTATIONS OF NATURAL OBJECTS.

Flowers, or other natural objects, should not be used as ornaments, but, instead thereof, we should use conventional representations founded upon them, sufficiently suggestive to convey the intended image to the mind without destroying the unity of the object they are employed to decorate. The former is called the NATURALISTIC *style of ornamentation, the latter the* CONVENTIONAL *style.*

Although this rule has been universally obeyed in what are deemed the classic periods of art, it has been equally violated when art has been on the decline.

A fragile flower, or a delicate vine, carved in wood, stone, or iron, shocks our feeling of consistency—an impropriety of which the Egyptians, the Greeks, and the early Romans were never guilty. They made *conventional* representations of natural objects, strictly adhering to their general laws of form; and hence their ornaments, however conventionalized (but more especially those of the Egyptians), were always true to nature, while they never, by a too servile imitation of the type, destroyed the consistency of the representation.

When flowers *in miniature* are carved upon precious stones, or even in iron, the delicacy of the workmanship may overcome our sense of the unfitness of things. The flower, leaf, vine, and fruit ornaments on vases and fruit-dishes are certainly not beautiful except when of diminished size; and even then, if carved, they should be executed in slight relief, or merely etched in outline.

In contradistinction, however, to the use of color and form as mere accessories in industrial art, when we come to the fine art of painting, and employ it to give a representation of real objects or scenes in nature, or of those which fancy creates, it is the naturalistic method which should prevail; for here the leading idea is a faithful portraiture of what is seen or imagined; and all other ideas must be subordinate to it. Here conventionality of representation would defeat the very object in view.

III.

ORNAMENTAL ART AMONG DIFFERENT NATIONS, AND IN DIFFERENT PERIODS OF CIVILIZATION.

I. ORNAMENT OF SAVAGE TRIBES.

THE desire for ornament is universal, and it increases with all people in the ratio of their progress in civilization. Every where it owes its origin to man's ambition to create —to imitate the works of the Creator. In the tattooing of the human face the savage strives to increase the expression by which he hopes to strike terror on his enemies or rivals, or to create what appears to him a new beauty; and it is often surprising how admirably adapted are the forms and colors he uses to the purposes he has in view. After tattooing usually comes the formation of ornament by painting or stamping patterns on the skins used for clothing, or on woven cloths or braided matting. Then follows the carving of ornaments on their utensils or weapons of war. When the principal island of the Friendly group was first visited, one woman was found to be the designer of all the patterns on cloths, matting, etc., in use there; and for every new one, she received, as a reward, a certain number of yards of cloth.

What strikes us especially in most ornamental work of savages, is the adherence to that rule of art which requires a skillful balancing of the masses, whether of form or color, and a judicious correction of the tendency of the eye to run in any one direction, by interposing lines that have an opposite tendency. (See Prop. ix.)

Captain Cook, noticing the extent to which decoration was carried by the Islanders of the Pacific and South Seas, aks of their cloths, their basket-work, their matting, etc., ainted "in such an endless variety of figures that one might suppose they borrowed their patterns from a mercer's shop, in which the most elegant productions of China and Europe are collected, besides some original patterns of their own."

II. EGYPTIAN ORNAMENT.

The origin of art among the Egyptians is unknown; and in their architecture, the more ancient the monument the more nearly perfect is the art. As far back as we can trace their ornamentation, a few of the more important natural productions of the country formed the basis of the immense variety of ornament with which the Egyptians decorated their temples, their palaces, dress, utensils, articles of luxury, etc.

All Egyptian art was *symbolic.* Thus the lotus and papyrus, growing so luxuriantly on the banks of the Nile, the former symbolizing food for the body, and the latter, being used for parchment, and thus symbolizing food for the mind; certain rare feathers carried before the king, and thus symbolizing royalty; the branches of the palm, and twisted cord made from its bark, etc. — such natural products were conventionally used in their decoration; and hence they were types of Egyptian civilization. A lotus conventionally carved in stone, and forming a graceful termination to a column, was a fitting symbol both of plenty and prosperity, and of the power of the king over countries where the lotus grew; and thus the ornament added a poetic idea to what would otherwise have been but a rude support.

On this basis of symbolism, Egyptian art was of three kinds:

1st. *Constructive.*—Thus, an Egyptian column represented an enlarged lotus or papyrus plant, or a bundle of such plants; the base representing the root, the shaft the stalk, and the capital the full-blown flower surrounded by a bouquet of smaller plants tied together by bands. And as the column represented one plant, three, or a greater number, and so of the other parts, the variety of form to which the various combinations gave rise was far beyond what any other style of architecture ever attained to.

2d. *Representative.*—In their *representation* of objects, every thing—as a flower, *for* example—was portrayed, not as a reality, but as an *ideal* representation. They did not attempt to portray the *real* flower, but something that should give the idea *of* one; and hence they adhered to the principles of the growth of plants, in the radiation of leaves, and all veins on the leaves, in graceful curves from the main stalk, or the stem. (See Prop. x.) They took the general form of the lotus plant, and changed it into the form of the base, shaft, and capital of a column, while it still retained sufficient resemblance to the lotus plant to show whence the idea originated. And so on, in all their art representations. (See Prop. xi.)

3d. *Decorative.*—All the paintings of the Egyptians, produced by few types, are distinguished by graceful symmetry and perfect distribution of parts. They painted every thing; but using color as they did form, *conventionally*, and to distinguish one part from another, they dealt in flat tints only, using neither shade nor shadow; and they indifferently colored the leaves of the lotus green or blue.

III. ASSYRIAN AND PERSIAN ORNAMENT.

The Assyrian and Persian ornaments which have been discovered seem to belong to a period of decline in art, and to have been borrowed, far back in the obscurity of ages, from an original and more nearly perfect style—perhaps that from which the Egyptian itself was derived.

Assyrian ornament is represented in the same way as the Egyptian, although it is not based on the same types; and indeed the natural types are very few. Yet the natural laws of radiation from the parent stem, and tangential curvature, are observed, although not so strictly as in Egyptian art. In both styles, the carved ornaments, as well as those that were painted, are mostly in the nature of diagrams—geometrial patterns being closely adhered to. The little surface modeling that was attempted was mostly slight relief.

IV. GREEK ORNAMENT.

Greek art, borrowed partly from the Egyptian and partly from the Assyrian, gave to old ideas of ornament a new direction. Rising rapidly to a high state of perfection, it carried the development of pure form to a degree of fitness and beauty which has never since been reached; and, from the very abundant remains we have of Greek ornament, we are led to believe that the presence of refined taste among the people was almost universal, and that the land was overflowing with artists, whose hands and minds were so trained as to enable them to execute with unerring truth those beautiful ornaments which to this day are the great wonder of art. Greek ornament, never in profusion or excess, was always strictly subordinate to the general expression of the object to which it was affixed.

But Greek art was not symbolical like the Egyptian; it was meaningless, purely decorative—the very embodiment of beauty for beauty's sake—and hence wholly æsthetic; seldom representative; and it can hardly be said to be constructive. The conventional rendering of natural objects was so far removed from the original types as often to make it difficult to recognize any attempt at imitation. The ornament was no part of the construction, and was thus unlike the Egyptian; it could be removed, and the structure remain unchanged. On the Corinthian capital, that leading feature of Grecian ornament, the acanthus leaf, is applied, not constructed as a part of the edifice. In the Egyptian, the whole capital, conventionally representing the full-blown flower of the lotus plant, is the ornament; and to remove any part would destroy the whole.

The three great laws which we find every where in nature—radiation from the parent stem, proportionate distribution of the areas, and the tangential curvature of the lines—are always obeyed in Greek art, and with so great a degree of perfection that the attempt to reproduce Greek ornament is rarely done with success.

There is now little doubt that the white marble temples of the Greeks were entirely covered with painted ornament.

This certainly was true as to the ornaments of the mouldings on architrave, frieze, and cornice; and doubtless the object in these cases was to render the mouldings and carvings distinct, and make the pattern visible from a distance.

V. POMPEIAN ORNAMENT.

Pompeii, a town of Italy, fifteen miles south-east from Naples, was destroyed by an eruption of Mount Vesuvius in the year A.D. 79. It has since been extensively excavated, disclosing the city walls, streets, temples, theatres, the forum, baths, monuments, private dwellings, domestic utensils, etc., the whole conveying the impression of the actual presence of a Roman town in all the circumstantial reality of its existence two thousand years ago.

Pompeian ornamentation was of two kinds — partly of Grecian and partly of Roman origin—but sufficiently distinct from either to require a separate notice in the history of ornamental art. That derived from the Greek was composed of *conventional* representations of objects in flat tints, without shade or attempt at relief; the other, more Roman in character, was based mainly upon the acanthus scroll, and was interwoven with natural representations of leaves, flowers, animals, etc.—the germs of a later Italian style of ornamentation. But the Pompeian style was exceedingly capricious, beyond the range of true art. The Pompeian pavements are the types from which may be traced the immense variety of Byzantine, Arabian, and Moresque mosaics.

VI. ROMAN ORNAMENT.

The temples of the Romans were overloaded with ornament; and the general proportions of Roman edifices, and the contours of their moulded surfaces, were entirely destroyed by the elaborate surface modeling carved on them. Nor do the Roman ornaments grow naturally from the surface like the conventional forms of the Egyptian capital: they are merely applied to it. The acanthus leaves, which by the Greeks were beautifully conventionalized, were used by the Romans with too close an approximation to nature: they were also arranged inartistically, being not even bound together by the necking at the top of the shaft, but merely resting upon it. In the Egyptian capital, on the contrary, the stems of the flowers round the bell-shaped capital being continued through the necking, at the same time represent a beauty and express a truth. The introduction of the Ionic volute—a Grecian feature—into the Roman Composite order, fails to add a beauty, but rather increases the deformity. The leaf ornamentation of the Romans adhered to the principle of one leaf growing out of another in a continuous line, leaf within leaf, and leaf over leaf—a principle very limited in its application; and it was only in the later Byzantine period that this style began to be abandoned for the true one of a continuous stem throwing off ornaments on either side. Then pure conventional ornament began to receive a new development. The true principle became common in the eleventh, twelfth, and thirteenth centuries, and is the foundation of the Early English foliage style.

While Roman Decorative Art abounds in the most exquisite specimens of drawing and modeling, its great defect consists in its frequent want of adaptation to the purposes it was required to fill as an aid to the true expression of architectural design. Roman decoration, like the Grecian, was strictly æsthetic—based on an almost reverential regard for the beautiful, for beauty's sake alone.

VII. BYZANTINE ORNAMENT.

When in the year A.D. 328 the Emperor Constantine transferred the seat of the Roman government to Byzantium (afterward called *Constantinople*, from its founder), Roman art was already in a state of decline, or transformation. Constantine employed Persian and other Oriental artists, and artists from the provinces, in the decoration of his capital; and these together soon began to work a change in the traditional Roman style, until at length the motley mass became fused into one systematic whole during the long and (for art) prosperous reign of the first Justinian. (A.D. 527 to 565.)

Byzantine art is characterized by elliptical curved outlines, acute-pointed and broad-toothed leaves, and thin continuous foliage springing from a common stem. In sculpture the leaves are beveled at the edge, and deeply channeled throughout, and drilled, at the several springings of the teeth, with deep holes. Thin interlaced patterns are preferred to geometrical designs; animal or other figures are sparingly introduced in sculpture, while in color they are principally confined to subjects of a holy character. Rome, Syria, Persia, and other countries, all took part as *formative* causes in the Byzantine style of art and its accompanying decoration. The character of the Byzantine school is strongly impressed on all the earlier works of Central and even Western Europe, which are generally termed the *Romanesque* or Romanized style, which is considered a fantastic and debauched style when applied to architecture. The geometrical mosaic work of Byzantine art belongs particularly to the Romanesque period, especially in Italy. This art, which flourished principally in the twelfth and thirteenth centuries, consists in the arrangement of small diamond-shaped pieces of glass into a complicated series of diagonal lines. *Marble* mosaic work differs from the glass only in the material used.

The influence of Byzantine art was all powerful in Europe from the sixth to the eleventh century, and even later; and it has served in a great degree as the basis of all the modern schools of decorative art in the East and in Eastern Europe.

VIII. ARABIAN ORNAMENT.

As every distinct form or mode of civilization has been characterized by its own peculiar style of art, so when the religion of Mohammed spread with astonishing rapidity over the East about the middle of the seventh century, and over Spain in the early part of the eighth, a new style of art arose, which gradually encroached, in those regions, upon the already waning glories of the Byzantine period.

Some of the Arabian mosques of Cairo, erected in the ninth century, remarkable alike for the grandeur and simplicity of their general forms, and the refinement and elegance of their decoration, are among the most beautiful buildings in the world. Their elegance of ornamentation was probably derived primarily from the Persians, perhaps modified by Byzantine influence. In their leafage ornaments we observe traces of Greek origin, especially in the modified form of the acanthus leaf; but they abandoned the principle of leaves growing out one from another, and made the scroll continuous without break, while they retained that universal principle of true art, the radiation of lines from a parent stem, and their tangential curvature. Like the Romans, they covered the floors of their public buildings with mosaic patterns arranged on a geometrical plan; but it is surprising that, while the same pattern forms of mosaics exist in Roman, Byzantine, Arabian, and Moorish art, the general style of each differs widely from all the others. It is like the same idea expressed in four different languages. The twisted cord, the interlacing of lines straight or curved, the crossing and interlacing of two squares, and the equilateral triangle within a hexagon, are the starting-points in each.

What is called *Arabesque* ornament consists of a fanciful, capricious, and ideal mixture of all sorts of figures of men and animals, both real and imaginary; also all sorts of plants, fruit, and foliage, involved and twisted, and upon which the animals and other objects rest. The Arabians did not originate this style, although it is named from them; and in *pure* Arabesque, figures of animals are excluded, as they were forbidden by the Koran.

It is strange that while the Arabians have left traces of fine Saracenic art all through Northern Africa, and in Spain, scarcely a vestige of it can now be found in their native country, Arabia.

IX. TURKISH ORNAMENT.

Although the Turks and the Arabians have the same religion, yet, being of different national origin, their art representations are, as might be expected, somewhat different. The architecture of the Turks, as seen at Constantinople, is mainly based upon the early Byzantine monuments, except their modern edifices, which are designed in the most European style. Their system of ornamentation is of a mixed character — Arabian and Persian floral ornaments being found side by side with debased Roman and Renaissance details. The art instinct of the Turks is quite inferior to that of the East Indians. The only good examples we have of Turkish ornamentation is in Turkey carpets; and these are chiefly executed in Asia Minor, and most probably not by Turks. The designs are thoroughly Arabian. The Turk is unimaginative.

X. MORESQUE OR MOORISH ORNAMENT.

In the ornamental art of the Moors, who established the seat of their power in Spain during the eighth century, we have another illustration of the results produced by corresponding influences of religious faith and diversities of national character. The main differences between the Arabian and Moorish edifices consist in this: that the former are distinguished most for their grandeur, the latter for their refinement and elegance. In ornamentation the Moors were unsurpassed; and in it they carried out the principles of true art, even beyond the attainments of the Greeks themselves.

Arabian and Moorish art were alike wanting in symbolism; but the Moors compensated for this want by the beauty of their ornamental written inscriptions, and the nobleness of the sentiments they expressed. To the artist these inscriptions furnished the most exquisite lessons in art; to the people they proclaimed the might, majesty, and good deeds of the king; and to the king they never ceased to declare that there was none powerful but God; that He alone was conqueror, and that to Him alone was ever due praise and glory. A law of the Mohammedan religion forbade the representation of animals, or of the human figure.

In the best specimens of Moorish architecture the decoration always arises naturally from the construction; and, although every part of the surface may be decorated, there is never a useless or a superfluous ornament. All lines grow out of one another in natural undulations, and every ornament can be traced to its branch or root; and there is no such thing as an ornament just jotted down to fill a space, without any other reason for its existence.

The best Moorish ornamentation is found in the Alhambra, a celebrated palace of the Moorish kings, at Granada, in Spain. This immense and justly famous structure, of rather forbidding exterior, but gorgeous within almost beyond description, was erected in the thirteenth century; and much of it remains perfect at the present day. It has been said by a competent judge that "Every principle which we can derive from the study of the ornamental art of any other people is not only ever present here, but was by the Moors more universally and truly obeyed." And further, that "We find in the Alhambra the speaking art of the Egyptians, the natural grace and refinement of the Greeks, and the geometrical combinations of the Romans, the Byzantines, and the Arabs." The walls of the Alhambra were covered with a profusion of ornamentation, which had the appearance of a congeries of paintings, incrustations, mosaics, gilding, and foliage; and nothing could be more splendid and brilliant than the effects that resulted from their combinations. The mode of piercing the domes for light, by means of star-like openings, produced an almost magical effect.

XI. PERSIAN ORNAMENT.

The Mohammedan architecture of Persia, and Persian ornamentation, are alike a mixed style, and are far inferior to the Arabian, as exhibited in the buildings at Cairo. The Persians, unlike the Arabs and the Moors, mixed up the forms of natural flowers and animal life with conventional ornament.

XII. EAST-INDIAN ORNAMENT.

Numerous manufactures calculated to give a high idea of the ingenuity and taste of the people of British India appeared in the Great Exhibition of the Industry of all Nations, in London, in 1851. Among these were various articles in agate from Bombay, mirrors from Lahore, marble chairs from Ajmeer, embroidered shawls, scarfs, etc., from Cashmere, carpets from Bangalore, and a variety of articles in iron inlaid with silver. In the application of art to manufactures the East Indians exhibit great unity of design, and skill and judgment in the application, with great elegance and refinement in the execution. In these respects they seem far to surpass the Europeans, who, says Mr. Owen Jones, "in a fruitless struggle after novelty, irrespective of fitness, base their designs upon a system of copying and misapplying the received forms of beauty of every bygone style of art." All the laws of the distribution of form which are observed in the Arabian and Moresque ornaments are equally to be found in the productions of India, while the coloring of the latter is said to be so perfectly harmonized that it is impossible to find a discord. This, of course, refers to the selected articles placed on exhibition in 1851.

XIII. HINDOO ORNAMENT.

We have but little reliable information about the ancient, or Hindoo, architecture of India; yet we know this much, that the Hindoos had definite rules of architectural proportion and symmetry. One of their ancient precepts, quoted by a modern writer, says, "Woe to them who dwell in a house not built according to the proportions of symmetry. In building an edifice, therefore, let all its parts, from the basement to the roof, be duly considered."

The architectural features of Hindoo buildings consist chiefly of mouldings heaped up one over the other. There is very little marked character in their ornaments, which are never elaborately profuse, and which show both an Egyptian and a Grecian influence.

XIV. CHINESE ORNAMENT.

Notwithstanding the great antiquity of Chinese civilization, and the perfection reached in their manufacturing processes ages before our time, the Chinese do not appear to have made much advance in the fine arts. They show very little appreciation of pure form, beyond geometrical patterns; but they possess the happy instinct of harmonizing colors. Their decoration is of a very primitive kind. The Chinese are totally unimaginative; and their ornamentation is a very faithful expression of the nature of this peculiar people—oddness.

XV. CELTIC ORNAMENT.

The Celts—the early inhabitants of the British Isles—had a style of ornamentation peculiarly their own, and singularly at variance with any thing that can be found in any other part of the world. Celtic ornament was doubtless of independent origin, but it every where bears the impress received by the early introduction of Christianity into the islands.

The chief peculiarities of Celtic ornament consist, first, in the entire absence of foliage or other vegetable ornament; and, secondly, in the extreme intricacy and excessive minuteness and elaboration of the various patterns, mostly geometrical, consisting of interlaced ribbon-work; diagonal, straight, or spiral lines; and strange, monstrous animals or birds, with their tail-feathers, top-knots, and tongues extended into long interlacing ribbons, which were intertwined in almost endless forms, and in the most fantastic manner. Celtic manuscripts of the Gospels were often ornamented with a great profusion of these intricate designs.

What is called the Celtic ornamentation was practiced throughout Great Britain and Ireland from the fourth or fifth to the tenth or eleventh centuries. There was a later Anglo-Saxon ornamentation, equally elaborate, employed in the decoration of manuscripts of the Gospels and other holy writings; but here leaves, stems, birds, etc., were introduced, and interwoven with gold bars, circles, squares, lozenges, quarterfoils, etc.

XVI. MEDIÆVAL OR GOTHIC ORNAMENT.

The high-pitched gable and the pointed arch, with a consequent slender proportion of towers, columns, and capitals, are the leading characteristics of mediæval or Gothic architecture, which came into general use in Europe in the thirteenth century. Mediæval Gothic art, like the Egyptian, was symbolic, deriving its types from the prevailing religious ideas of the period. Thus the churches and the cathedrals of the Middle Ages were built in the form of a cross—the sign and symbol of the Christian faith. The numbers three, five, and seven, denoting the Trinity, the five traditional wounds of the Saviour, and the seven Sacraments, were preserved as emblematical in the nave and two aisles, in the trefoiled arches and windows, in the foils of the tracery, and in the seven leaflets of the sculptured foliage; while the narrow-pointed arches, and the numerous finger-like pinnacles, rising above the gloom of the dimly lighted place of worship, symbolized the faith which pointed the soul upward from the trials of earth to the happy homes of the redeemed. The transition from the Romanesque (later Roman) or rounded style to the pointed is easily traced in the numerous buildings in which the two styles are intermingled; but the passage from Romanesque ornament to Gothic is not so clear. In the latter, new combinations of ornaments and tracery suddenly arise. The piercings for windows become clustered in groups, soon to be moulded into a network of enveloping tracery; the acanthus leaf disappears; in the capitals of columns of pure Gothic style, the ornament arises directly from the shaft, which, above the necking, is split into a series of stems, each terminating in a conventional flower—the whole being quite analogous to the Egyptian mode of decorating the capital.

In the interior of the early Gothic buildings every moulding had its color best adapted to develop its form; and from the floor to the roof not an inch of space but had its appropriate ornament, the whole producing an effect grand almost beyond description. But so suddenly did this profuse style of ornament attain its perfection, that it almost immediately began to decline. What is called *ornamental illumination*, that is, the decoration of writing by means of colors, and, especially, the decoration of the initial letters to pages of manuscript, attained a high degree of perfection under the influence of the Gothic style.

While Gothic ornamentation retained its *conventional* character, there was a boundless field for development: when it became a mere imitation of natural objects, and represented stems, flowers, insects, etc., true to life, all ideality fled, and there could be no further progress in the art.

XVII. RENAISSANCE ORNAMENT.

The fact that the soil of Italy was so covered with the remains of Roman greatness that it was impossible for the Italians to forget them, however they might neglect the lessons they were calculated to teach, was probably the reason why Gothic art took but little root in Italy, where it was ever regarded as of barbarian origin. When, in the fifteenth century, classical learning revived in Italy, and the art of printing disseminated its treasures, a taste for classic art revived also; and the style of ornamentation to which it gave rise, formed upon classic models, is called *Renaissance* ornament; and the period of its glory the Restoration, or *Renaissance* period.

A combination of architecture and decorative sculpture was a distinguishing feature of the Renaissance style. Figures, foliage, and conventional ornaments were so happily blended with mouldings, and other structural forms, as to convey the idea that the whole sprung to life in one perfect form in the mind of the artist by whom the work was executed. To Raphael (early in the sixteenth century), both sculptor and painter, we owe the most splendid specimens of the *Arabesque* style, which he dignified, and left with nothing more to be desired. (See Arabian Ornament.) Arabesques lose their character when applied to large objects; neither are they appropriate where gravity of style is required.

All the great painters of Italy were ornamental sculptors also. Their sculptured ornaments were ingeniously arranged on different planes, instead of on one uniform flat surface, so as best to show the diversities of light and shade. Much of the splendid painting done by the Italian masters, from Giotto to Raphael—from the year 1290 to 1520—was mural decoration, now generally called *fresco*. In true fresco, the artist incorporated his colors with the plaster before it was dry, by which the colors became as permanent as the wall itself. This kind of painting was so clear and transparent, and reflected the light so well, as to be peculiarly suited to the interior of dimly lighted buildings; and it is said that the eye which has been accustomed to look upon it can scarcely be reconciled to oil pictures. It is a well-known saying of Michael Angelo, that fresco is fit for men, oil painting for women, and the luxurious and idle.

XVIII. ELIZABETHAN ORNAMENT.

The revival of art in Italy soon spread over France and Germany, and about the year 1520 extended into England, where it soon triumphed over the late Gothic style. The true Elizabethan period of art embraced only about a century. It is simply a modification of foreign models, and has little claim to originality.

The characteristics of Elizabethan ornament may be described as consisting chiefly of a grotesque and complicated variety of pierced scroll-work, with curled edges; interlaced bands, sometimes on a geometrical pattern, but generally flowing and capricious; curved and broken outlines; festoons, fruit, and drapery, interspersed with roughly executed figures of human beings; grotesque monsters and animals, with here and there large and flowing designs of natural branch and leaf ornament; rustic ball and diamond work; paneled compartments, often filled with foliage, or coats of arms, etc., etc.: the whole founded on exaggerated models of the early Renaissance school. By the middle of the seventeenth century the more marked characteristics of the Elizabethan style had completely died out.

MODERN ORNAMENTAL ART.

There is, no doubt, a very decided tendency in modern ornamental art to copy natural forms as faithfully as possible for all decorative purposes. We see this, alike, in our floral carpets, floral wall-papers, floral curtains, and in the floral carvings of our structures of wood, stone, and iron. Yet when perfection shall have been attained in this mode of ornamentation—if it has not been already—and which is but the mere copying of nature, and devoid of all originality of design, how little has the artist accomplished in the development and application of art principles, and what further can he attain to?

But when, on the contrary, the progress of true art shall be acknowledged to lie in the direction of *idealizing* the forms of nature—giving to them a conventional representation while adhering to the *principles* of natural growth, in the manner in which art grew up among the Egyptians and the Greeks—the artist will be left free to follow the bent of his genius, and to select from, and conventionally adopt, whatever natural forms he may find best suited to his purposes. Then there may be advance in art beyond the copying and intermingling of those olden styles, which now excite in us but little sympathy; but until then we shall probably rest content in the idea that all available modes and forms have been used by those who preceded us, and that there are no untrodden domains of art left for us to explore.

PART II.

PRINCIPLES AND PRACTICE OF INDUSTRIAL DRAWING.

DRAWING-BOOK No. I.

I. MATERIALS AND DIRECTIONS.

1. For Paper to draw on, use "*Willson's Cabinet Drawing-Paper*" for Drawing-Books Nos. I., II., III., and IV. This paper is printed in fine red or pink lines, to correspond to the ruling in the Drawing-Books; and it has a border so ruled and lettered as to furnish convenient guides for the accurate drawing of the diagonal and semi-diagonal lines of Cabinet Perspective, as illustrated in the Second, Third, and Fourth Drawing-Books. Of this drawing-paper, No. 1 is the same in size as the pages in the Drawing-Books, and No. 2 is four times the size. There is also "*Isometrical Drawing-Paper No.* 1," of the same size as the No. 1 Cabinet Drawing-Paper, for use in isometrical drawings, as illustrated in the Appendix to this volume. The fine pink lines of the drawing-paper do not in the least interfere with the pencil drawings.

2. For Pencils, use Faber's Nos. 1, 2, 3, and 4, which are round black pencils. No. 4 being the hardest of these, is used for fine, hard lines only, or very light shading; No. 3 for common outline drawing and shading; and No. 2 for heavy and distinct dark lines and edges. No. 1, very dark and soft, is little used. There are also very superior Faber pencils, of light wood, hexagonal in form, and numbered by letters H, HH, HHH, and HHHH: H being soft pencils, and HHHH very hard and fine.

There are also what are called the *Eagle* pencils—the H pencil for light shading and lines, and the F for common shading. The common Eagle pencils marked 1, 2, and 3, are of inferior grade.

3. For most industrial drawings, however, India ink is more convenient, and better, for *shading*, than the pencil. A cake of good India ink, about two inches long, that will go further in shading than a hundred pencils, may be bought of almost any bookseller or stationer for some twenty or thirty cents. Two or three camel's-hair pencils (or brushes) will also be needed. Price, three or four cents each. To use the ink, put half a teaspoonful, or less, of water in a small saucer (or the smallest china plate, about two inches in diameter; or a small glass salt-cellar is better), and rub one end of the India-ink cake in it, giving the water the depth of tint that is required. With one of the brushes *flow* the ink over those portions of the drawing that are to be shaded. When the ink is dry, apply the wash a second time to those portions that require a darker shade than the lighter portions, and apply it a third time to those portions, if any, that require a still darker shade. In this manner any required depth of even shade may be given. Be careful and not make the ink too dark at first; and, as it dries up quite rapidly in the saucer, water must be supplied from time to time to keep it of a uniform tint. It produces a good effect to first wash lightly, with India ink, those portions of a drawing that require shading; and then, when the ink is dry, to put on the line shading with the pencil.

4. For many of the curvilinear drawings, in which parts or wholes of perfect circles are used, a pair of *compasses* adapted to receive a pencil will be needed; or, what will answer the purpose very well, a pencil may be split and tied firmly to one of the legs of a pair of ordinary brass compasses or dividers.

5. A *ruler* will also be needed for drawing long straight lines. It should be beveled off on one side to a very thin edge. A ruler with one thin metallic edge is the most convenient.

6. For the purpose of *Blackboard Exercises* in connection with drawing on paper, every school in which industrial drawing is taught should be provided with a blackboard of convenient size, having *fine red lines* painted on it, both vertically and horizontally, at right angles to one another,

and two inches apart. Any careful painter can prepare a board in this manner. The board should not be varnished. The red lines drawn on the board will interfere very little with the use of the board for ordinary purposes. The school should also be provided with one pair of *chalk-crayon compasses*, for the drawing of regular curves on the blackboard. Any ingenious carpenter can make a pair that will answer very well. One of the points may be hollowed out to receive the crayon, which may be tied in.

7. All the figures in a lesson, or on a page of the Drawing-Books, should be first copied by the pupils on the lined drawing-paper, and then the accompanying *Problems* should be drawn, and then the free-hand blackboard exercises, when such are suggested. The pupils should also explain the drawings fully—their measurements according to the scale given on the paper, and their *real* measures when drawn on the blackboard. But if any of the pupils are too young to understand the few elementary principles of surface measurement that are given in Drawing-Book No. I., these principles may be passed over for the present, as they will come up again in a more extended exposition of the Drawing, Measurement, and Relations of Surfaces and Solids.

8. Although *free-hand drawing* can be carried out in the present series quite as extensively as in any other series, and perhaps with more effect than in any other, as the guide-lines at once detect all inaccuracies; and although this kind of preliminary practice is important for all designers in art, and especially for *artists by profession*, yet we would remind teachers and pupils that it is never relied on by architects, draughtsmen, and artisans for the drawing of working-patterns or designs for industrial purposes, and that most of the copies which are given in the drawing-books for practice in free-hand drawing are there executed, with elaborate care, by the aid of ruler and compass. Even the best of artists do not hesitate to resort to all possible mechanical appliances by which their work can be improved; and it would be strange, indeed, if we should deny to children those aids which we allow to age and ex-

perience. While, therefore, we recommend free-hand drawing in elementary exercises, and also in all portions of copies or original designs which can be well executed thereby, we would advise advanced pupils to make use of all other aids that are essential to accuracy of result. Frequent directions are given throughout the work for free-hand exercises in drawing on the blackboard.

9. For the purpose of getting the full effect of a drawing in diagonal Cabinet Perspective (Books II., III., and IV.), partially close the hand, and through the tubular opening thus formed look at the drawing from a position a little above and at the right of it. On thus viewing it intently for half a minute, the drawing will seem to stand out in bold relief from the paper; and if there are any inaccuracies in the perspective, they will be readily detected by the unnatural appearances which they will thus be made to present.

10. If the teacher should find some few slight inaccuracies in which the diagrams in the Drawing-Books do not fully come up to the descriptions of them, they must attribute it to the occasional want of care in the artists who copied them from the original drawings. The errors, however, are believed to be few, and of little importance; and the teacher who gets hold of the principles will easily correct them.

11. It should be remarked, also, that drawings in pencil and India ink, if well executed, and especially if made on the pink-ruled drawing-paper, will be clearer in shading, more distinct in outline, and will show to better advantage generally, than those in the Drawing-Books.

☞ 12. For convenience of adapting the explanations of drawings given in the Drawing-Books to those made on the blackboard, let it be understood that the lines on the blackboard are in all cases (unless otherwise directed) supposed to be drawn *to the same scale* as those assigned for the lines of the printed drawings.

II. STRAIGHT LINES AND PLANE SURFACES.

PAGE ONE.

LESSON I. *Horizontal Parallel Lines.—A horizontal line* is a line that has all its points equally high, or on a level with the horizon. *Parallel lines* are lines that extend in the same direction, and that are equally distant from one another, however far they may be extended. Thus, the lines that cross the paper from left to right are *parallel* lines, one eighth of an inch apart; and they are also *horizontal* lines when the paper lies flat upon the table, and also when it is raised to an upright position. All the lines in Lesson I. may be considered *horizontal* and *parallel.*

In drawing the copies on this page, use a No. 3 or No. 2 pencil, rounded at the point, and not *sharp.* Use no ruler. In figure No. 1, draw all the lines on the fine-ruled horizontal red lines seen on the drawing-paper—first tracing each line very lightly, carrying the pencil a part of the time from left to right, and a part of the time from right to left, so as to acquire a free command of the hand. Finish by drawing each line firm and distinct, and as true and even as possible. In the first column the lines are one eighth of an inch long; in the second column two eighths, or one quarter of an inch; and in the third column three eighths of an inch long. The printed vertical and horizontal lines in the Drawing-Book, and also on the drawing-paper, are *one eighth* of an inch apart.

In No. I., the pencil lines are drawn on the ruled lines, one eighth of an inch apart; in No. II., they are first drawn the same as in No. I., and then a line is drawn between every two; in No. III., *two* lines are drawn equally distant between every two lines first drawn as in No. I. No. III. represents coarse shading. Let the pupil imitate the foregoing with free-hand drawing on the red-lined blackboard, and tell the lengths of the lines thus drawn—as two inches four inches, six inches, etc.; and their distances apart.

LESSON II. *Vertical Parallel Lines.* — *A vertical line* is one that is exactly upright in position—such a line as that which is formed by suspending a weight by a string. The lines in Lesson II. *represent* vertical lines; but they are really vertical only when the paper is placed in an upright position, and with the heading of the page upward. These vertical lines are *parallel*, for the same reason that those in Lesson I. are parallel.

Draw the lines in Lesson II. from the top downward, first going over each line lightly, once or twice; and, when the line is accurately traced from point to point, finish by marking it firmly.

What are the respective lengths of the lines in No. 1? In No. 3? In No. 4?

In Nos. 2 and 3 the lines are drawn at the same distances apart as in the corresponding numbers of Lesson I. In No. 4, *three* lines are drawn equidistant between the ruled lines. No. 2 represents *coarse* shading; No. 3, *ordinary* shading; and No. 4, *fine* shading.

Free-hand exercises on the blackboard, similar to those directed for Lesson I.

LESSON III. *Angles, and Plane Figures.* — No. 1 represents two right angles, *x*, *x*, formed by one line meeting another. An *angle* is the opening between two lines that meet.

When one straight line (*a b*) falls upon another straight line (*c d*), so as to make the adjacent angles (*x*, *x*) equal, the two angles thus formed are *right angles.* The angle at *x*, No. 2, is also a right angle.

An *acute* angle (*e*) is an angle that is less than a right angle; an *obtuse* angle (*n*) is an angle that is greater than a right angle.

A *plane* is a *surface*, on which, if any two points be taken, the straight line which joins them touches the surface in its whole length.

Nos. 3, 4, and 5 are *plane* figures called *squares.*

A *rectilinear* plane figure is a plane figure bounded by straight lines.

A *square* is a plane figure that has four equal sides and four right angles. Nos. 3, 4, and 5 are squares. They are also called *erect* squares, because two of the sides of each are erect, or vertical.

A *rectangle* is a four-sided figure having only right angles. The term is generally applied to those rectangular (right-angled) figures which are not squares. Nos. 6, 7, and 8 are rectangles. Nos. 9 and 10 may be divided into rectangles.

Principles of Surface Measurement.

We will suppose that throughout Drawing-Book No. I. the direct distance from one line to another on the ruled paper is one inch, unless otherwise directed.

Then, how much space will one of the small ruled squares contain? (One square inch.) How much will four of them contain? (Four square inches.) As a standard of measurement, each of the small squares formed by the ruling of the paper is called a *primary* erect square.

How large is No. 3? (One inch square.) How much area, or surface, does it contain? (One square inch.)

How large is No. 4? (Two inches square. That is, it measures two inches on each side.) How much area, or surface, does it contain? (Four square inches, as may be seen by counting the primary squares within it.)

How large is No. 5? (Four inches square.) How much area, or surface, does it contain? (Sixteen square inches.)

How large is No. 6? (Two inches by three inches.) How much area, or surface, does it contain? (Six square inches.)

How large is No. 7, and what is its area? How large is No. 8, and what is its area?

Hence,

To find the area or surface measurement of any rectangle:

RULE I.—*Multiply the length by the breadth, and the product will be the area.*

PROBLEMS FOR PRACTICE.

1. Draw a square of three inches to a side. What is its area?
Ans. 9 square inches.

2. Draw a square of nine inches to a side. What is its area?
Ans. 81 square inches.

[illegible] Draw a rectangle of four by five inches. What is its area?
(Ans. 20 square inches.)
[illegible] Draw a rectangle of six by eight inches. What is its area?
(Ans. [illegible]

Let the Pupil draw the foregoing Problems on the Blackboard.

No. 4 has *twice* the length of sides of No. 3. How many times larger than No. 3 is it? (*Four* times larger; because No. 3 contains one square inch, and No. 4 contains four square inches.)

No. 5 has *four* times the length of sides of No. 3. How much larger than No. 3 is it? (*Sixteen* times larger.)

No. 5 has *twice* the length of sides of No. 4. How much larger than No. 4 is it? (*Four* times larger.)

No. 7 has twice the length of sides of No. 6. How much larger is No. 7 than No. 6? (*Four* times larger.)

From the foregoing it appears that, by increasing the lengths of the sides of a square or a rectangle to *two* times their length, we form a similar figure *four* times as large; by increasing to *three* times, we form a similar figure *nine* times as large; by increasing to *four* times, we form one *sixteen* times as large; by increasing to *five* times, we form one *twenty five* times as large, etc. The same principle holds true with *regard* to a figure of *any number of sides*.

ELEMENTARY PRINCIPLE. *The areas of similar plane figures are as the squares of their similar sides.*

If, therefore, we have a plane figure of any number of sides, and wish to make another similar to it, but *four times* as large, we *double* the lengths of the sides; because 2 times 2 are *four*: if we wish to make one *nine* times as large, we *treble* the lengths of the sides; because 3 times 3 are *nine*: if we wish to make one *sixteen* times as large, we *quadruple* the lengths of the sides; because 4 times 4 are *sixteen*, and so on to the square of any given number.

☞ Let the teacher explain more fully, if necessary, what is meant by *the square* of a number, and especially that number represents the *length* of a given line.

PROBLEMS FOR PRACTICE.

1. Draw a square similar to No. 3, but nine times as large.
2. Draw a square similar to No. 4, but nine times as large.
3. Draw a square similar to No. 4, but twenty-five times as large.
4. Draw a rectangle similar to No. 6, but nine times as large.
5. Draw a rectangle similar to No. 6, but four times as large.
6. Draw a polygon similar to No. 10, but four times as large.

A *polygon* is a plane figure having many sides and many angles. The term is generally applied to a plane figure of more than four angles and four sides.

Free-hand exercises on the blackboard.—Let the pupil follow out, on the blackboard, a course of exercises similar to those prescribed for the tint-lined drawing-paper.

LESSON IV. *Diagonals.—Diagonals* are lines drawn in the direction of a diagonal of a primary erect square.

A *primary* diagonal is a line drawn diagonally from one corner to another of a primary erect square.

No. 1 is made up of primary diagonals in two directions.

No. 2 is a *primary diagonal* square. What is its area equal to? (Two square inches; inasmuch as it includes four halves of the small *primary erect* squares.)

What is the area of No. 3?*

What is the area of No. 4? No. 5? No. 6?

If No. 2 have its sides *doubled* in length, how much larger will the figure be?

If No. 2 have its sides *trebled* in length, how much larger will the figure be?

PROBLEMS FOR PRACTICE.

1. Draw a diagonal square similar to No. 2, but sixteen times as large; that is, containing sixteen times the area of No. 2. How long must the sides be, compared with the sides of No. 2?
2. Draw a diagonal square similar to No. 2, but twenty-five times as large. How long must the sides be, compared with the sides of No. 2?
3. Draw a diagonal square similar to No. 3, but nine times as large.
4. Draw a diagonal rectangle similar to No. 5, but four times as large.

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* The *halves* of square inches included within the figures in this lesson might be marked with *dots*, for greater facility in counting them.

[illegible]

[illegible]

[illegible] direction from which

the light is supposed to come. Thus, in No. 4, the light is supposed to come in the direction of the arrow *a;* and hence the outlines are made the heaviest where the shadows would naturally fall.

No. 5. Observe the direction in which the light falls upon this figure, as indicated by the arrow *b*, and the consequent heavy outlines of those sides of the four pieces which would be in shadow.

The shading in No. 7 should render each square distinct from the others.

No. 8 is a pattern made up of only one figure, repeated continuously, and so arranged as to cover the entire surface. A very great variety of patterns, consisting wholly of repetitions of one figure to each pattern, may easily be designed, and drawn by the aid of the ruled paper.

What is the area of each of the squares, as they are numbered, in No. 7.

The area of the pattern figure in No. 8 ?

Free-hand exercises on the blackboard.

PAGE TWO.

LESSON VI. *Two-space Diagonals.*—By a *two-space* diagonal is meant the diagonal of a rectangle which is twice as long as it is broad. It is a diagonal which passes over *two spaces* on the ruled paper.

No. 1. The lines in No. 1 are two-space diagonals. They should be copied, without the aid of a ruler, until they can be drawn with tolerable accuracy, and with facility. At *b* lines are first drawn as at *a;* and then lines are drawn intermediate between them; *c* is first drawn the same as *b*, and is then filled in with intermediates. In this manner great uniformity of shading may be attained.

No. 2 is drawn in a manner similar to No. 1. First trace each line lightly, and continue to pass the pencil over it until it is drawn with accuracy.

No. 3. As two square inches are represented in the dotted rectangle, and as the line *a b* divides the rectangle into two equal parts, therefore on each side of the line there is an area equal to one square inch.

[illegible] embraced within the dotted square [illegible] embraced within the portion [illegible]

[illegible] embraced within the dotted rectangle [illegible] embraced within the portion [illegible]

[illegible] a *triangle* — a figure of three sides and [illegible] angled triangle, because each angle is less than [illegible] The portion marked *a* in No. 5 is called [illegible] of the angles is greater than a right [illegible]

[illegible] A *rhombus* is a figure [illegible] opposite sides being parallel [illegible] What area is embraced [illegible] whole figure [illegible]

[illegible] parts of [illegible] whole rhombus [illegible]

[illegible] of the [illegible] area of [illegible] shown in No. 4 and [illegible] same [illegible] contain an [illegible]

[illegible] No. 2 [illegible] area of [illegible]

[illegible] equal [illegible]

[illegible] No. 1 [illegible] point [illegible]

[illegible]

[illegible] of arriving at [illegible] working drawings. In industrial [illegible] the different sides or surfaces of objects very distinctly by the shading; and this is one of the kinds of shading very appropriate for that purpose.

No. 13. What is the area of each of the rhombuses marked *a?* (See No. 4 and No. 6.) What is the area of the central star figure? (See No. 11.) What is the area of the whole octagon?

No. 14. What is the area of each of the rhombuses marked *a?* (See No. 9.) Of each of the star points marked *b?* (See No. 4.) Of the central square *c?* Of the whole octagon?

PROBLEMS FOR PRACTICE.

1. Draw a rectangle similar to the dotted rectangle No. 4, but four times as large. (See ELEMENTARY PRINCIPLE, page 54.)

2. Draw a triangle similar to *a* of No. 4, but nine times as large. How must the sides compare in length with those of *a* of No. 4? What will be the area of the triangle?

3. Draw a triangle similar to *a* of No. 5, but containing sixteen times the area of No. 5.

4. Draw a rhombus similar to No. 6, but containing twenty-five times the area of No. 6. Shade it with two-space diagonals like *b*, or *c*, of No. 1.

5. Draw a rhombus similar to No. 7, but containing only one fourth the area of No. 7.

6. Draw a figure similar to the *a* portion of No. 8, but sixteen times as large.

7. Draw a rhombus similar to No. 9, but containing twenty-five times the area of No. 9.

8. Draw a rhombus similar to No. 10, but having four times the area of No. 10.

9. Draw a star figure similar to No. 11, but containing nine times the area of No. 11.

10. Draw an octagon similar to No. 12, but containing four times the area of No. 12.

11. Draw an octagon similar to No. 13, but containing nine times the area of No. 13. Divide it as No. 13 is divided, and mark within each rhombus its area, and mark the area of the star also.

12. Draw a figure similar to No. 14, but sixteen times as large, and mark within the parts *a*, *b*, and *c* the area of each.

Let problems similar to the foregoing be drawn on the blackboard, or selections from them, at the option of the teacher.

LESSON VII.—No. 1 is a *two-space* diagonal square; and No. 2 is the same in a different position. The area of No. 1 can easily be counted up, when it is seen that each of th [illegible] lesson [illegible]

[illegible] outside of the mailer [illegible]

2. Draw a rectangle similar to No. 4, but embracing four times the area of No. 4.

3. Draw a rectangle similar to No. 6, but embracing four times the area of No. 6.

4. What area would be included in a two-space diagonal rectangle having a length of eight two-space diagonal measures, and a breadth of five? (See Rule B.)

5. Draw a pattern similar to No. 10, but with the figures embracing four times the area of those in No. 10.

6. Draw a pattern similar to No. 11, but with the figures embracing four times the area of those in No. 11.

Free-hand drawing of problems similar to the foregoing on the blackboard.

LESSON VIII. *Three-space Diagonals.*—By a *three-space* diagonal is meant the diagonal of a rectangle which is three times as long as it is broad. Thus, the diagonal of the rectangle at *a*, No. 1, passes over *three spaces*, and divides the rectangle into two equal parts. As the rectangle includes an area of three square inches, each half of it, as marked *1*, has an area of one and a half square inches.

No. 2. What area is included in the dotted rectangle No. 2? In each of the three parts, *a*, *b*, and *c?*

No. 3 is a three-space diagonal square. Observe that each of the parts marked *1* has an area of *one and a half* square inches. Then what is the area of the whole square? (*Ans.* 10 square inches.)

No. 4 is a rhombus. What is its area? The area of the dotted rectangle?

No. 5 is a three-space diagonal rectangle. Its area is easily found, by counting, to be twenty square inches. But the area of any three-space diagonal square, or other three-space diagonal rectangle, however large, may easily be found by the following rule, also a modification of Rule I.

To find the area of a three-space diagonal rectangle:

RULE C.—*Multiply the length in three-space diagonals by the breadth in three-space diagonals, and* TEN *times the product will be the area, in measures of the primary erect squares.*

Thus, in the square No. 3, the length 1, of one side, multiplied by 1, the length of another side, gives the product

1, which, multiplied by 10, gives 10 square inches as the area.

Apply the rule to No. 5, and test the result by counting. What is the area?

No. 6. What is the area of the inner dotted rectangle? Of the large rectangle? Then what is the area of the space included between the two?

No. 7. The area of the space included within the dotted figures *1*, *2*, *3* is seen, by counting, to be five square inches. But the area of the part marked *a* is one and a half square inches, and the area of *c* is the same, the two parts *a* and *c* making three square inches. Therefore the part *b* embraces two square inches.

No. 8. What is the area of the rhombus No. 8?

No. 9 is a three-space diagonal octagon. What is the area of each of the parts *a*, *b*, *c*, and *d?* Of the inner dotted square? Of the whole octagon?

No. 10. What is the area of the four rhombuses *a*, *b*, *c*, *d?* Of the star *g?* Of the whole octagon?

No. 11. What is the area of the four rhombuses *a*, *b*, *c*, *d?* Of the four parts *e*, *f*, *g*, *h?* Of the central square *k?* Of the whole octagon?

No. 12. What is the area of the star in No. 12? What is the area of the star in No. 8 of Lesson VII.? What is the difference in their areas?

Let all the foregoing be drawn on the drawing-paper.

PROBLEMS FOR PRACTICE.

1. Draw, on the drawing-paper, a three-space diagonal square that shall contain 9 times the area of No. 3.

2. Draw a rhombus similar to No. 4, but containing nine times the area of No. 4. Within the rhombus thus drawn, and equidistant from its sides, draw a rhombus containing four times the area of No. 4. Within this latter, and equidistant from its sides, draw another equal to No. 4. Mark the rhombuses thus drawn No. 1, No. 2, and No. 3, beginning with the smallest, and mark the area of each.

3. Draw a rectangle similar to No. 5, but containing sixteen times the area of No. 5. Draw one within this latter containing four times the area of No. 5.

4. Draw a rhombus similar to No. 8, but containing four times the area of No. 8.

5. Draw an octagon similar to No. 9, but containing four times the area of No. 9.

6. Draw an octagon similar to No. 10, but with other interlacing octagons on its diagonal sides, similar to No. 10 of Lesson VII.

7. Draw an octagon similar to No. 11, but with other interlacing octagons on its vertical and horizontal sides, similar to No. 11 of Lesson VII.

8. Draw a star similar to *g* of No. 10, but having four times the area of *g*, and inclose it with an interlacing square similar to No. 7 of Lesson VII.

Free-hand drawing of problems similar to the foregoing on the blackboard.

PAGE THREE.

LESSON IX.—This lesson consists of a series of net-work, the finer examples of which, when used in drawing or engraving, for the purposes of shading, are called *hatching*.

No. 1 is a coarse diagonal net-work, in the form of squares.

No. 2 is drawn, in the first place, in the same manner as No. 1; after which another set of lines is put in, in both diagonal directions, intermediate between those first drawn.

No. 3 is first drawn the same as No. 2, after which another set of lines is put in intermediate between those first drawn. This kind of hatching is seen in No. 6 of the next lesson.

No. 4 is a coarse *two-space* diagonal net-work.

No. 5 is first drawn the same as No. 4, and is then filled in with another set of lines between those first drawn.

No. 6 is a fine hatching, first drawn the same as No. 5, and then filled in with another set of lines intermediate between those first drawn. A sharp-pointed, hard pencil is required for this shading.

No. 7 is a coarse *three-space* diagonal net-work. When filled in with two lines intermediate between those here drawn, it forms a good hatching for some kinds of shading.

All the examples in this lesson, which should be copied without the aid of a ruler, will furnish good exercises in drawing straight, uniform, and equidistant lines. The directions, and the distances apart, are given in the ruling of the paper.

Free-hand drawing of Lesson IX. on the blackboard.

LESSON X.—No. 1 gives the outline of a star-shaped figure; and No. 2 is the same divided into eight pairs of wings by a vertical, a horizontal, and two diagonal lines, and then shaded. This peculiar star-shaped figure is a common form of ornament in examples of Byzantine art. What is the area of each of the eight pairs of wings of No. 2? Of the whole star?

No. 3 is a star similar to No. 2, inclosed in a diagonal square, but with twice the length of sides of No. 2. How, then, does its area compare with that of No. 2? What is the area of the diagonal square? (See Rule A, page 56.)

No. 4 is a *hexagonal* pattern covering the entire surface. A *hexagon* is a plane figure of six sides and six angles. When the sides are all equal, and the angles all equal, it is a *regular* hexagon. What is the area of one of the hexagons of No. 4?

No. 5 is a pattern composed of an elongated octagonal figure and a square, the two forms combined covering the whole surface. What is the area of one of the octagons?

Nos. 4 and 5 may be varied so as to embrace a great variety of similar patterns by changing the relative lengths of the sides. Numerous oil-cloth and carpet patterns are formed on this basis. Additional variety is given to Nos. 4 and 5 by the bordering, as indicated at *a* and *b*. Observe that the exact distance of the inner lines from the outer border is given by the intersections of the ruled lines.

No. 6 is an original Moorish pavement pattern, called *mosaic;* but it is now common, with various modifications, in pavements, oil-cloths, etc. It is easily drawn on the ruled paper. The *hatching* used in the shading is that of No. 3 of Lesson IX.

No. 7 is an elongated hexagonal link pattern, for borders, etc. Observe the position of the *heavy* shaded lines on the right hand and lower sides.

No. 8 is a double interlacing square. First trace lightly.

PROBLEMS FOR PRACTICE.

1. Draw a star similar to No. 2, but nine times as large. What will be its area?

2. Draw a star similar to No. 2, but four times as large, and inclose it with a diagonal square similar to the inclosure of No. 3. Centrally within each of the corner diagonal squares similar to *a*, *b*, *c*, *d* of No. 3 place a star like No. 2 within its own diagonal square.

3. Draw a pattern made up of hexagons similar to those of No. 4, but of four times the area, and complete each in a manner similar to *a*.

4. Draw a pattern like No. 5, but with the exception that the shaded squares shall contain four times the area of those in No. 5. Complete the several hexagons in a manner similar to *b*.

5. Draw a pattern composed wholly of figures like No. 6. The addition at *a* will show how the several figures are to be connected. Shade all like No. 6, or use different tints of India ink.

6. Draw a link pattern like No. 7, with the exception that each link shall be two spaces *longer* than in No. 7, but of the same width.

Free-hand drawing of Lesson X., and the problems, on the blackboard.

Lesson XI.—No. 1 and No. 2 are the elements of slightly different patterns formed on the basis of either an erect or a diagonal square.

No. 3 is the basis of an octagonal pattern. At No. 4 the short lines *a a a a* show the method of marking out an inner octagon whose sides shall be uniformly distant from and parallel to the sides of the larger octagon; and No. 5 shows the figure completed.

No. 6 is the pattern, as carried out, from the preceding three figures. The central octagons should be shaded with a light tint of India ink, and the squares with the running dots in horizontal lines. The different kinds of shading used in the patterns given in these books denote the variety of colors employed when the pattern is used either in ornamental art, or in the designs of oil-cloths, carpets, wall-paper, etc.

No. 7 is a *dodecagon*—a figure of twelve sides and twelve angles. When the sides are equal, and the angles equal, the figure is a *regular* dodecagon. What is the area of each of the parts *a*, *b*, *c*, *d* of this figure? Of the central dotted square? Of the whole dodecagon?

No. 8 is a dodecagon divided into a border of squares and triangles, and a central hexagon. What is the area of each of the two vertical squares? Of each of the four two-space diagonal squares? Of each of the six white triangles that incloses the small dark triangle? Of the central hexagon? Of the whole figure?

No. 9 is a pattern composed wholly of intersecting dodecagons like No. 8. Each figure, it will be seen, forms a portion of six other like figures surrounding it. This combination of dodecagons is an original pavement pattern taken from a Roman church in the Byzantine period of Roman history. It is an admirable specimen of geometrical mosaic work so common in that period; and it must have been formed upon lines drawn precisely like those given on our ruled paper; for in no other manner could a series of such figures be drawn with accuracy.

PROBLEMS FOR PRACTICE.

1. Draw a pattern formed of figures like No. 1, allowing the figures to touch vertically and horizontally. Give to these figures the running *dot* shading; and shade the intermediate figures formed between them with a light tint of India ink.

2. Draw a pattern formed of figures like No. 2, and shade the diagonal cross with a tint of India ink, and the intermediate figures with the running dot shading. Leave the diagonal squares unshaded.

3. Draw a double interlacing square like No. 8 of Lesson X., and centrally within it draw a figure like No. 8 of Lesson XI.

Patterns similar to No. 6 and No. 9 may be drawn 4, 9, 16, 25, or 36 times, etc., larger than the figures here given, by increasing the lengths of the sides 2, 3, 4, 5, or 6 times, etc., according to the principles explained on pages 53 and 54.

Free-hand drawing of Lesson XI., and the problems, on the blackboard.

PAGE FOUR.

For convenience, we now drop the method of grouping the examples under the head of *Lessons*, and here designate them as separate *Figures*.

Fig. 1 represents an ancient Egyptian pattern of a braided or woven mat on which the king stood. It is formed of flat strands of only two colors, each strand passing continuously, in a diagonal direction, over two strands of different colors, and then under two. The portion of a strand presented at one view is rectangular, and twice as long as it is broad. All the lines in this figure are diagonals, and should be drawn without the aid of a ruler. The shaded strands may be gone over, first lightly, with India ink, and then with pencil.

Fig. 2 is another Egyptian pattern of matting, in only two colors, but presenting a view quite different from Fig. 1. Here each light strand passes continuously over two dark strands, and then under three dark strands. The dark strands may be considered as the *warp*, and are arranged side by side, all running diagonally; and then the light strands, being the *filling*, are woven in diagonally, as stated, at right angles to the warp. Patterns similar to Figs. 1 and 2 may be formed of worsted of two colors.

Fig. 3 is the pattern of an Arabian pavement found at Cairo, formed of black and of white marble, except the diagonal squares, which are of red tile. Go over the diagonal squares once, and the rectangles twice, with a light tint of India ink. The Arabians imitated the universal practice of the Romans of covering the floors of their public buildings, mosques, etc., with mosaic patterns arranged on a geometrical system.

Fig. 4 is a decorative pattern, in different colors, from an ancient Egyptian tomb. It is supposed to have suggested the *meander*, or *fret*, to the Greeks. (See page 6 of drawings.) The ruler may be used in this figure, after first indicating the lines with the pencil alone.

Fig. 5 is an ancient Egyptian pattern, in different colors, from the painting on a tomb. In most of these Egyptian paintings the colors are as fresh as if put on yesterday.

Fig. 6 is an octagonal pattern forming intermediate figures of diagonal squares. The ruled lines furnish convenient guides for forming the width of the octagon border.

Figs. 7 and 8 are samples of mosaic patterns based upon two of the forms of the central eight-pointed star figure, so common in specimens of Byzantine ornamental art.

Fig. 9 is another modification of the star figure in mosaic, here inclosed by an interlacing border.

Fig. 10 represents a portion of a mosaic pavement, in different colors, from the ruins of Pompeii. Observe that the running dotted shading is done very lightly, and with a sharp pencil, in Figs. 7, 8, and 9; but much more heavily, and with a blunt pencil, in a portion of Fig. 10.

[illegible]

[illegible] on the left. [illegible] beginning on [illegible]

Fig. 21 is a pattern of interlacing diagonal net-work, embracing diagonal squares that are distinguished by three forms of shading or coloring.

Fig. 22 represents an embroidered pattern brought a few years ago from the East Indies. Here the *forms* alone can be given, as the colors can not be represented. In the original pattern the four *stars* of each cross-shaped figure are white or silver, on a black ground inclosed by a silver line; and the small dark squares and the straight lines connecting them are golden.

Fig. 23 is the filling up of a mosaic pattern of Byzantine pavement. The numerous symmetrical figures that may be discerned in it show both the intricacy and at the same time the harmonious simplicity of the Byzantine style. By the aid of the ruled paper similar patterns of almost endless variety may be designed.

For free-hand drawing on the blackboard take Figs. 13, 14, 15, 16, 17, and 18. They may be shaded slightly with colored chalks, so as to make the interlacings plain.

PAGE SIX.

Fig. 24 is the simple generating form of the Grecian single *fret*, or *meander*—a species of architectural ornament consisting of one or more small projecting fillets, or rectangular bands, meeting, originally, in vertical and horizontal directions only. Although this ornament was originated by the Greeks, quite similar rudimentary forms of the fret have been found among the Chinese and the Mexicans. The Arabians extended the Greek fret to diagonal and curved interlacing bands; and the Moors afterward extended it to that infinite variety of interlaced ornaments, formed by the intersection of equidistant diagonal lines, which are so conspicuous a feature in the ornamentation of the Alhambra. In addition to the most important of the *plane surface* Grecian frets, here given, and some of the Moorish that are best adapted to drawing purposes, we have also shown several of them in the second number of the Drawing Series, in their more natural form in architecture, as *solids*.

Fig. 24 requires no directions for drawing it. Fig. 11, on [illegible] In [illegible]

[illegible] panels, although strictly [illegible] of Roman pavement that has [illegible] been found in the ruins of Pompeii. The two bands composing the fret, which are here differently shaded, were of white marble, formed of the same number of square pieces as is designated by the ruling of the paper; and the intermediate spaces, here left unshaded, were of black marble.

Fig. 32 is an interlacing double fret with panels.

Fig. 33 is a double fret with panels, but is not interlacing. Take away the panels, and the frets are doubly backed upon one another.

Fig. 34 is an interlacing double fret, formed of distinct portions connected by a rectangular link.

Fig. 35 is a diagonal and horizontal interlacing double fret; and, as its form shows, is not Grecian. It is of Moorish origin, and is one of the numerous kinds of complicated frets, painted in various colors, and on variously colored grounds, on panels of the walls of temples.

Fig. 36 is an interlacing double fret, also of Moorish origin.

For free-hand blackboard exercises take Figs. 28, 29, 34, and 36. They may be shaded lightly.

PAGE SEVEN.

Figs. 37 and 38 are borders of fret-work, formed after Moorish and Arabian patterns.

Fig. 39 is an Arabian pattern of a mosaic pavement, with some of the smaller subdivisions omitted. The peculiar star-form of ornamentation here shown, which is of Byzantine origin, was also used by the Arabians.

Fig. 40 is a diagonal double fret, which has been slightly varied from an Arabian pattern to fit it to our purpose. In copying it, either one of the bands should first be lightly traced throughout.

Fig. 41 consists of two four-pointed stars interlacing, so as to show an eight-rayed or eight-pointed star. In drawing it, first take the centre, *c*, then the four inner vertical and horizontal points marked *3*, then the four inner diagonal points marked *2*. Also take the eight ray points in a similar manner. Trace lines very faintly from the outer to the inner points; then trace an inner set of lines equidistant [illegible] alternate ray [illegible] the intersections [illegible] drawn. The rays [illegible] than those in the [illegible] considered that [illegible] spaces are [illegible] spaces.

Fig. [illegible] is copied from an Arabian pattern of a mosaic pavement [illegible] white [illegible] red and black. The groundwork may be said to consist of elongated [illegible] connected by interlacing diagonal squares; then there is a central interlacing fret ingeniously varied to adapt it to the other portions, so as to make a perfectly harmonious meander. In drawing it, first trace the three parts lightly in the order here described.

Fig. [illegible] is also copied from an Arabian mosaic, in white, red, and black. It is taken from a pavement in Cairo. It will be seen that the diagonal lines here are all two-space diagonals; and as the drawing conforms strictly to the original, it must be true that the original pattern was formed by the aid of precisely such horizontal and vertical lines as we have used for guides on the ruled paper.

Observe how beautifully the nine small figures, in three colors, and three different forms, fill out the six-pointed star-shaped figure at the intersection of the several bands. The entire pattern is a fine example illustrating the fundamental principles of decoration; that all ornament should be based upon a geometrical construction, and that every pattern should possess *fitness*, *proportion*, and *harmony*, the result of all which will be a feeling of satisfied repose, with which every such decoration will impress the beholder, leaving nothing further to be desired within the scope of the ornamentation.

For free-hand blackboard exercises take Figs. 37, 38, and 41. Observe the heavy shading on those sides that would be in shade if the light came in the direction indicated by the arrow.

III. CURVED LINES AND PLANE SURFACES.

PAGE EIGHT.

A *curved line* is one which is continually changing its direction. If the curve be uniform, it forms part of the circumference of a circle.

A *circle* is a plane bounded by a single curved line called its circumference, every part of which is equally distant from a point within it called the *centre*. The circumference itself is usually called a *circle*. A straight line drawn from the centre to any part of the circumference is called a *radius*.

Fig. 1. At *A* are six uniform curves of five spaces' span (five inches), and a depth of one space; and at Fig. 1 this curve forms part of a perfect circle. At *a* and *b* the directions of the curves are changed; but all combined form a harmonious and equally balanced figure, because the additions *a* and *b* are uniform in position and curvature. These figures should be drawn with the compasses, using the pencil to make the connections of the curves uniform. Let the pupil find the centres from which the curves *a* and *b* are struck.

Fig. 2 is formed of the same pattern curve used in different positions, but all combined to form a harmonious figure. If either of the half curves, *c* or *d*, were omitted, or changed in position, the harmony of the figure would be destroyed. At *Y* the same form of curve is used. Let the pupil find the centres from which the curves are struck.

Fig. 3 is also a harmonious figure, described wholly by the compasses; but the inner border lines from *e* to *h* and from *g* to *f* are described with a less radius than that used for the other curves. The curves *e i* and *g i* are, each, only half of the pattern curve, and are described from the points *1* and *2*.

Fig. 4. At *B* is another pattern curve representing a span of six inches and a depth of one inch, described from the centre *c*, with a radius of five inches. In the shaded four-angled figure the pattern curve is used in four different po-

[illegible] described [illegible]

[illegible] pattern [illegible] however, [illegible] with [illegible]

[illegible] combinations [illegible] pattern curve [illegible] described with [illegible] it will be easy for the [illegible]

[illegible] pattern curve [illegible] span [illegible] span and a half. This [illegible] circumference of a [illegible]

[illegible] combinations of the en- [illegible]

[illegible] portions of the pat- [illegible]

[illegible] seen that we may [illegible] curve, and com- [illegible] patterns. It is [illegible] can combine [illegible] same pattern, with- [illegible] is required [illegible] of repose [illegible]

[illegible] curves. [illegible] aid of [illegible] shall have a figure of harmonious form, whether *a x* be the *most* graceful line, by itself, that could be drawn, or not. But if *a x* should be drawn of the most graceful form possible, and *a y* just as graceful in itself, but differing from *a x*, the combination of the two graceful forms would be discordant, and make an inharmonious figure, because wanting in symmetry of parts.

Having, therefore, *a x*, we designate in it any number of points in which it crosses either the horizontal or vertical lines of the paper. Let *1*, *2*, *3*, *4*, and *5* be these points. Then dot, lightly, the *corresponding* points *1*, *2*, *3*, *4*, *5* on the other side of *a b*, and through them trace the curve, at first lightly, and afterward fill it out to correspond with the line *a x*. The figure is thus made perfectly *symmetrical*. The top of the figure may be either pointed or circular; and the bell may be longer, or narrower, or broader, or any one out of a great variety of suitable proportions; yet if the two sides are alike, the figure will not be unpleasant to the eye. The two inner dotted curves give different proportions for the bell, while the base remains the same.

Fig. 11 represents the harmonious outlines of a leaf form. Observe that the border lines of the leaf pass through the points *1*, *2*, *3*, *4*, *5*, on each side of the central line *c d*, corresponding to one other. Thus the points *1* are, each, one space from the central line; the points *2*, each two spaces; the points *3*, each three spaces, etc. In this manner the two sides of the leaf are made perfectly symmetrical. The radiations of the veins from the midrib of the leaf are also symmetrical.

Fig. 12 is another form of leaf, and although very different from Fig. 11 is equally harmonious in proportions. The pupil should now have no difficulty in copying it accurately on the ruled paper.

Fig. 13. Here is a group of eight uniform leaves, uniformly radiating from a common centre. The four points *a*, *c*, *e*, *g*, are, each, four spaces from the centre, and on lines at right angles with one another. Hence these four points are symmetrically arranged. The other four points, *b*, *d*, *f*, *h*, are in the *diagonals*, which are intermediate between the

other lines, and are, each, at the distance of three diagonals from the centre, a trifle *greater* than the distance of the other four points, but sufficiently accurate to give the figure all the symmetry required. Then each leaf must be drawn by hand. At *D* the method of beginning the drawing is shown; at *E* it is carried still farther forward; and in Fig. 13 it is completed.

PROBLEMS FOR PRACTICE.

1. Draw Fig. 1, and draw within it a curved line one space distant from the outer border line.
2. Draw Fig. 2 in the same manner.
3. Draw *Y* with an outer border line one space distant from the inner border line, and tint the space between the two.
4. Draw Fig. 3 inverted, with the upper part downward.
5. Draw the upper part of Fig. 5 on each of the four sides of the square *H*, so that it shall project in four directions from the central square.
6. Draw Fig. 10 of the same length as at present, but with a base, *x y*, of ten spaces.
7. Draw Fig. 11 eight spaces broad at *3 3*.
8. Draw Fig. 12 four spaces broader than in the book, and give to the figure a graceful curve throughout.

Blackboard Exercises.—Figs. 1 to 9 inclusive. For these a pair of chalk-crayon compasses will be needed. See directions, page 49.

PAGE NINE.

Fig. 14. The circle here drawn from the centre *c* has longitudinal divisions, by pure curves drawn from different points on the central vertical line.

Fig. 15. The irregular curve on the left of the central line *a b* had first to be drawn by the eye—the design being to form a graceful, well-proportioned curve. Its counterpart, on the other side of the line, is to be drawn in the manner directed for drawing the preceding figures, 10, 11, and 12.

Fig. 16 is Fig. 15 completed in outline; the two portions on each side of the central line *a b* being made symmetrical.

Fig. 17, the completed form, is a portion of a Pompeian border ornament, painted in yellow on a black ground. The central figure is proportioned symmetrically also. The whole is, doubtless, of Greek origin.

Figs. 18 and 19 are symmetrically formed leaves, the drawing of which now requires no farther explanation. Observe how perfectly the one side corresponds to the other, and how easy it is to draw such forms on the ruled paper.

Fig. 20, a common form of Grecian conventional leaf ornamentation, is arranged symmetrically on each side of a vertical central line.

Fig. 21, a conventional leaf form of ornamentation, can now be easily drawn.

Fig. 22, also a leaf form, is (or should be) equally balanced on each side of the line *a b*. Observe that the points *c* and *d* are at equal distances, horizontally, from the line *a b;* so also the points *e* and *f*, and *g* and *h;* and each leaf division on one side must have a corresponding division on the other side.

Fig. 23, a Grecian pattern, shows one of the many forms of *conventional* leafage found on Grecian vases. The leaf forms which the Greeks (and all the ancients) used in their ornamentation were far removed from any natural types; and while they are constructed on the general principles which reign in all plants, they never attempt to represent any particular species. The moderns, departing from the true principles of ornamentation which prevail in ancient art, attempt to give representations of *real* leaves, flowers, etc., being even guilty of the anomaly of sculpturing the most delicate flowers in stone!

Observe that the two portions of each pattern figure are arranged, symmetrically, on each side of a central line (as *a c*), which equally divides not only the inclosing border, but the symmetrical group of leaves also. Therefore one half of each group is first to be drawn, and then the other half is to be made to correspond to it, as shown in preceding figures. The pupils should trace the leaf forms very lightly at first.

Fig. 24 is the form of a Grecian ornament, painted in gold on a blue ground, on a sunken panel of the ceiling of a Grecian temple. Here, also, it will be observed, the *leafage* is purely conventional in form, and not designed to represent any particular group in nature.

The pattern is arranged symmetrically around the centre *c*, the diagonals and diameters dividing it into four equal portions. Taking the upper quarter section, observe that the points of the leaves *b b* are equidistant from the central line; the slender volutes bend over equally in graceful curves, and the remaining foliage below them fills the figure with graceful forms symmetrically disposed. Having the ruled paper, the pattern can be accurately drawn without difficulty.

PROBLEMS FOR PRACTICE.

After the pupil has copied the examples on page 9, let him draw the following:

1. Draw a figure similar to Fig. 17, but two spaces higher, and two spaces narrower.

2. Draw Figs. 18 and 19, each four spaces longer, and of the same width, in the widest parts, as in the book.

3. Draw Fig. 21 symmetrically, on a smaller scale.

4. Let the pupil design a figure similar to Fig. 22, but of different proportions.

5. Let the pupil draw the pattern figures in Fig. 23, each two spaces higher, but of the same width as at present.

Blackboard Exercises.—Figs. 16, 18, 19, 20, 21, and 22.

PAGE TEN.

All the patterns on this page are plain examples of what is called *Renaissance ornament;* by which is understood the style of ornamentation which sprung up in Italy upon the revival of art after the Dark Ages. (See page 41.). The examples here given are from beautiful colored specimens of glazed pottery of the sixteenth century.

Fig. 25. In copying this pattern the outlines should first be drawn lightly, as shown at *A*. First draw a single-line outline of all the figures in the pattern, making each figure symmetrical on each side of its central line; then finish the two-line border of each figure. The minor divisions of each figure can then easily be drawn.

Fig. 26. The outlines of this figure are to be drawn by the compasses, as shown at *B*. Thus, the points *a* are the centres of the semicircles which make up the general outline of the pattern.

Fig. 27. In this pattern the outer semicircle of each figure is drawn from the centre *a*, with a radius of five spaces;

and the inner and smaller curves are described from the points *b*, *c*, *d*, etc.

Fig. 28. While the lower portion of this *bulb pattern* is to be drawn with the compasses, they can afford no aid in drawing the upper portion. The outlines of the central row of bulbs are first to be drawn of uniform curves on both sides, for which the ruling will be a perfect guide.

PROBLEMS FOR PRACTICE.

1. Draw and shade Fig. 25 in full, after the enlarged outline form shown at *D*.

2. Draw and shade Fig. 26, according to the enlarged outline form shown at *C*, which is four times the size of the pattern. Why is it four times the size?

3. Draw an outline of one of the series in Fig. 27, four times its present size.

4. Draw Fig. 28 lengthwise of the paper, and four times its present size.

Blackboard Exercises.—The bulb-pattern Fig., and Fig. 25, enlarged as at *D*.

PAGE ELEVEN.

Fig. 29 is a Grecian pattern of a painting on vases. It is still another example of conventional flower representation, in which only the general principle of the pendulous flower-bud is retained. It is drawn with the greatest regard to symmetry. The right-hand portion, left partly unshaded, shows how the forms of the pendulous buds are drawn symmetrically, and of uniform size.

Fig. 30 is a Byzantine interlaced circular pattern, sculptured in stone, from Milan, Italy. It is very easily drawn, almost wholly by the compasses. Trace the whole very lightly at first. The light is supposed to come diagonally from above, from the right hand.

Fig. 31 is a copy of one of the Assyrian painted ornaments found among the ruins of Nineveh. The central circles, *a* (see the end marked *B*), were black; the inclosing ring, *b*, dark reddish brown; the winding band, *c*, orange; and the other winding band, *d*, blue; while the spaces within the borders, outside of the winding bands, had a groundwork of reddish brown. The blue winding band was separated from the orange, wherever they were contiguous, by a black line. Thus the ancient Assyrians understood the now admitted principle that one color should never impinge upon another, and that all contiguous colors should be separated, generally by either white or black lines. The entire pattern may be easily and accurately drawn by the compasses. The same pattern is also found differently lined and colored, somewhat as shown at the end marked *C*.

Fig. 32 is a Byzantine pattern of interlaced ornament, to be drawn wholly by the compasses. The central points from which the several circles and semicircles are described can easily be found by the pupil.

Fig. 33 is a partially completed pattern, showing the method of putting in a series of uniform divisions that radiate from the centre of a circle. The circle is easily divided into *eight* equal parts by lines radiating from the centre on the vertical, horizontal, and diagonal lines, as indicated by the lettering. Each eighth of the circumference is then to be divided into three equal parts by the compasses, and the opposite points in the circumference are connected by slightly traced or dotted lines passing through the centre. The *bases* of the radiating white stars can then be designated with sufficient accuracy by the eye, as the points to which the sides of the stars are to be drawn, on the second circle, are intermediate between the radiating dotted lines. Figures similar to this are numerous in ancient ornamental art.

Fig. 34 is a Byzantine pattern of interlacing circles. Though seemingly intricate, it is quite easily drawn, and wholly by the compasses. It would, however, be impossible to draw it with any approach to accuracy without the aid of the ruled paper; and there can be no doubt that it was originally drawn on a ground prepared with lines such as those we have given. The ruling gives the exact centre of every circle, and renders all measuring unnecessary. Observe that the heavy shadows indicate that the light comes from above, and from the left. The background may be shaded with a uniform tint of India ink, or by the pencil, as indicated in the upper left-hand portion.

Fig. 35 is also a Byzantine interlaced ornament, a considerable portion of which may be drawn by the compasses.

Thus the three circular bands, and the projections of the interlacing loops as described from the vertical, horizontal, and diagonal centres *a*, *a*, *a*, etc., are all easily and accurately drawn. The connecting and interlacing of the loops centrally must be done by hand, guided by the eye alone; but after having drawn one of the connections, as from *b* to *d*, the others may be drawn in symmetrical conformity to it. Observe how the shadows are cast, the light coming diagonally from the left, and from above.

PROBLEMS FOR PRACTICE.

1. Draw a pattern similar to Fig. 29, but let the semicircular black line, from the end of which the flower-bud is suspended, be drawn with a radius of *four* spaces, instead of three; and let the flower-bud be two spaces longer and one space broader at the broadest part.
2. Draw a pattern similar to Fig. 31, but describe the larger circles with a radius one space greater than in the figure.
3. Draw a pattern similar to Fig. 33, but describe the outer circle with a radius of eight spaces, and divide each eighth part of the circumference into *four* equal parts, instead of three, thus giving to each eighth part one ray more than in the figure.
4. Draw Fig. 34 on a larger scale, having the radius of the larger circles six spaces, instead of five.
5. Draw Fig. 35 on a larger scale, at the option of the pupil.

Blackboard Exercise.—So much of Fig. 35 as there is room for on the board. It would require a board four feet square to draw it in accordance with the enlarged ruling of the board.

PAGE TWELVE.

We have given on this page a number of original designs, for the purpose of indicating the facility with which an immense variety of very pleasing patterns may be drawn almost wholly by the compasses alone.

Fig. 36 is an ornamental figure called a *quarterfoil*, inclosed within a circle. The quarterfoil, often used in architecture, is disposed in four segments of circles, and is a *conventional* representation of an expanded flower of four petals. The lettering shows with what ease and accuracy it is drawn on the ruled paper.

Fig. 37 is an ornamental figure consisting of *eight* segments of circles, described from the eight numbered points which are at the extremities of the dotted *vertical*, *horizontal*, and *diagonal* lines. After drawing these dotted lines, of indefinite extent, but all passing through the centre *c*, equidistant points in all of them, for describing the segments, may be found by cutting the lines with the circumference of a circle described from the centre *c*. From the points *1*, *2*, *3*, *4*, etc., the segments are described with a length of radius that will barely allow the inner segments of circles to touch one another.

Fig. 38. The segments of circles are here drawn in a manner similar to those shown in Fig. 37; and then these segments are connected by ribs passing through the centre. The intervening spaces are then shaded, so as to give the filling-up a raised and rounded appearance, the heaviest shades being found on the lower right-hand portions—the light being indicated by the arrow *A* as coming diagonally from the left hand, and from above. The spaces covered by the heavy dark shade on the outside borders of the figure—the heaviest at the right and below—are marked out accurately by the compasses, by moving the fixed point of the compasses uniform distances, diagonally, from the centres *1* to the points *2*. By looking at the figure through a tubular opening, it will seem to stand out from the paper as if embossed upon it—*in relief.*

Fig. 39 is similar in its border outlines to Fig. 38; and all of it, with the exception of the central portion, may be easily and accurately drawn, and mostly shaded, by the compasses alone. To draw the central figure accurately, first trace out lightly, in the space which it covers, the vertical, horizontal, and diagonal lines, after which the raised wedge-shaped oval figures may be drawn in between these lines by hand. Observe how the heavy shadows are formed.

Fig. 40, drawn on the same general plan as the preceding two figures, requires no additional explanation. The shaded cross-ribs are easily drawn after making the raised circles of uniform size around their given central points. As these central points are determined by the tint lines on the drawing-paper, the whole figure may be drawn with the greatest ease and accuracy.

Fig. 41 is a pattern of seeming intricacy, but very easily drawn, and planned on the same general principles as the preceding figures on the same page. Every thing is drawn by the compasses from points indicated by the ruling of the paper, except the raised wedge-shaped ovals, that look as if embossed.

Fig. 42 is an interlaced pattern, drawn wholly by the compasses, with the exception of the central figure. The figures *1*, *2*, *3*, *4*, etc., show the eight central points from which the interlacing curves are described.

Blackboard Exercises.—Figures 41 and 42, omitting the central eight-leaf flower patterns.

Page 12 of this book illustrates, very happily, the great advantage which the ruled paper affords for drawing curvilinear patterns. It would be next to an impossibility to draw these designs with accuracy without this aid; but with this ruling, this kind of drawing, which is used to a great extent in all the decorative arts, becomes a very simple matter, easy of attainment by all who can describe a circle by the aid of the compasses.

DRAWING-BOOK No. II.

CABINET PERSPECTIVE—PLANE SOLIDS.

THE *Cabinet Perspective* presented in this series is a method of representing solids, both plane and curvilinear, in such a manner that the drawings shall give, by the aid of the ruled paper, the correct measurements of the objects represented. The ruling on the paper is adapted to any scale of measurement; but, for the purposes of the present illustration, let it be supposed that the vertical and horizontal lines on the paper are respectively one inch apart.

In all drawings in what is called *Diagonal Cabinet Perspective,** objects are supposed to be viewed in a manner similar to that in which the two cubes† in Fig. 1, on page 1 of Drawing-Book No. II., are represented. Taking the cube at *B* for illustration, this may be supposed to be a cube six inches square, the front face of which is in a vertical position. The spectator is supposed to view this cube from such a point, above and at the right of the cube, that he may see just as much of the upper side of the cube as of the right-hand side; so that the apparent width, *10 9* of the upper face, or *12 0* of the side face, shall measure, in the directions indicated, one half the width of the front face; and so that the diagonal corner lines, *1 2*, *3 4*, and *5 6*, will seem to rise diagonally at an angle of forty-five degrees; while the distance from which the view is taken is supposed to be so great that these lines will appear to be, as they are here drawn, *parallel.*

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* There is a beautiful practical application of Cabinet Perspective, called *Semi*-diagonal Cabinet Perspective, which will be found illustrated on pages 9–11 of Drawing-Book No. IV. See page 171.

† A *cube* is a regular solid body, having six equal square sides.

The front face of the cube is drawn in its real proportions as a square, and as though it were seen in a vertical plane directly fronting the spectator. According to the scale supposed to be adopted in the ruling, the front of the cube measures six inches to a side. The farther face of the cube, being also vertical and parallel with the front face, and therefore in a plane also directly fronting the spectator, would also be drawn as a square if it could all be seen, measuring six inches to a side. Hence each of the lines *2 4* and *4 6* measure six inches, the same as *1 3* and *3 5.*

But each of the *diagonal* lines *1 2*, *3 4*, and *5 6*, being corner lines of the cube, must also *represent* a measure of six inches; and as each of these lines extends over three diagonals of the small squares, it follows that what we call *one* diagonal space measures *twice* as much as a vertical or a horizontal space, *whenever this diagonal space is applied to the measurement of a line representing a horizontal line.* We may, therefore, adopt the following rule for the measurement (and also for the drawing) of all objects in diagonal cabinet perspective.

ELEMENTARY RULE.

Drawings of surfaces that are supposed to be in a vertical plane fronting the spectator are measurable, in any direction, according to the scale adopted for the vertical and horizontal spaces of the ruling; while each DIAGONAL *space that measures a line in a horizontal and diagonal position is to be taken as* TWICE *the measure of a space of the other kind.*

Applying this rule to the cube at *B*, Fig. 1, we find that all the horizontal lines, and also all the vertical lines that cross the front face of the cube, measure each six inches in length, because each extends over just six of the ruled spaces, and all are in a vertical plane fronting the spectator. For a similar reason each one of the *vertical* lines on the right-hand side of the cube, and each one of the *horizontal* lines on the top of the cube, measures six inches, because each may be supposed to be in a plane like that which forms the front face of the cube—directly fronting the spectator. But such lines as *1 2*, *3 4*, *5 6*, *8 9*, *10 11*, and *12 13*, being seen *obliquely*, can not be in any plane fronting the spectator; and as they lie in a diagonal direction, and represent horizontal lines, they are measurable by the principle adopted in the latter part of the rule. Hence the line *a b* measures five inches; *c d* four inches; *g 13* four inches; *m n* six inches: but *8 9* measures six inches; *10 11* measures four inches; *12 13* measures four inches, etc. The cube at *A* measures two inches on each of its corners.

Fig. 2. Applying the scale of measurement which we have adopted to the representation of the cube at *D*, Fig. 2, we find that the front face of the cube is a square of four inches to a side; and that the diagonal horizontal distance *1 2*, or *3 4*, or *5 6*, also measures four inches. Also, if we draw intermediate lines between the ruled lines on the paper, on the upper face and right-hand face of the cube, so as to give *one*-inch diagonal measures, then sixteen one-inch squares may be counted on each of the three visible faces or sides of the cube. We thus have, according to the scale of *one* inch to a space horizontally or vertically between the lines, and *two* inches for a diagonal space, the exact measurement of the three visible sides of the cube.

To find the contents of a cube:

RULE.—*Multiply the length of a side of the cube by itself, and that product again by a side, and this last product will give the contents required.* (See Rule I., page 53, for the measurement of surfaces.)

Thus, in the cube at *D*, Fig. 2, if we multiply the length (*1 2*) of one side, which is four inches, by the length (*2 4*) of another side, which is also four inches, we get the product 16, which is the number of solid cubic inches contained in the upper tier of the cube—as may also be seen by counting them; and as there are four of these tiers, we multiply the 16 by 4, and get 64, the number of cubic inches in the four tiers, or in the whole cube. Or, $4 \times 4 \times 4 = 64$ cubic inches.

One cubic inch is represented at *C*, which, according to the scale we have adopted for page 1, measures one inch on each of its sides; and at *E* are sixteen cubic inches, equal to the upper tier in *D*.

In straight-line drawings in cabinet perspective, the *ruler* may be used wherever its aid will give additional accuracy to the drawing.

The contents of the cube *B*, Fig. 1, which measures six inches to a side, are found by the rule to be as follows.

Ans. $6 \times 6 \times 6 = 216$ cubic inches.

The drawing at *E*, Fig. 2, is an example of a *parallelopiped;* a figure which is defined as being a solid whose faces are six rectangles,* the opposite faces being parallel, and equal to each other. The drawing at *F* also represents a parallelopiped. All squares are parallelopipeds; but all parallelopipeds are not squares.

To find the contents of a rectangular (right-angled) parallelopiped:

RULE.—*Multiply the length by the breadth, and that product by the depth, and this last product will give the contents required.*

The height of the rectangular solid at *E*, Fig. 2, is one inch; the breadth in one direction (*1 2*) is four inches; and the breadth in the other direction (*3 4*) is also four inches. What are the contents? *Ans.* $1 \times 4 \times 4 = 16$ cubic inches, as may be verified by counting the small one-inch cubes which it contains.

The length (or height) of the solid at *F* is three inches; the breadth or width is five inches; and the diagonal depth is two inches. What are the contents?

Ans. $3 \times 5 \times 2 = 30$ cubic inches.

The two rules just given may be combined in one, as follows:

To find the contents of any solid rectangular figure:

RULE.—*Multiply the three dimensions together, and their product will be the contents required.*

Fig. 3. At *G*, *H*, *I*, and *J* are represented four parallelopipeds, all of the same size; *G* being viewed in a vertical position, *H* horizontally, and *I* and *J* horizontally and diagonally. They may be considered pieces of timber, each two inches square at the ends, and twelve inches long. What are the solid contents of each? *Ans.* 48 cubic inches.

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* In a strict definition the sides need not, necessarily, be rectangular (right-angled); but it is better, at present, for the pupil in drawing to consider all parallelopipeds as of the rectangular kind.

Observe that, according to the scale of measurement already explained, these pieces measure precisely the same in these three different positions.

Fig. 4. According to the definition of a parallelopiped, this figure, also, is one of that kind. What are its measurements, and its contents?

Observe that the right-hand sides of the foregoing figures are represented as shaded with a deep tint of India ink, the front with a lighter tint, and the top of Fig. 4 with the running dotted shading. The kinds of shading used in Fig. 4 are well adapted to all plane solids, as the object of shading, in cabinet perspective, is to render the several surfaces as marked and distinct as possible, one from another.

Fig. 5 is a square frame composed of four pieces, each two inches square; the two diagonal side-pieces each twelve inches long, and the other two each eight inches long. What is the size of the square which they *inclose?*

Fig. 6. Let the pupil describe Fig. 6—that is, tell how many pieces compose the figure, their size, position, etc.

Fig. 7 is drawn, first, in the same manner as *G* of Fig. 3; it is then divided so as to represent cubical blocks, each two inches square, placed one above another. Three of these blocks are represented as shaded with the *hatching* described in Lesson IX. of Drawing-Book No. I., after first tinting the surface with India ink.

Fig. 8 is composed of two vertical blocks, each two inches square and five inches long, resting upon the ends of a piece one inch by two inches, and twelve inches long; the latter being viewed diagonally.

Fig. 9 is the same as No. 8 inverted, and still viewed diagonally.

Fig. 10 is also the same as Fig. 8; but it is here viewed horizontally. Thus the same figure may be represented in several different positions, so as to bring each side into full view.

In these several figures observe the effect of the shading, which is rapidly executed with different tints of India ink, except the upper surfaces, which have the running dot-line shading.

PROBLEMS FOR PRACTICE.

1. Draw the representation of a square frame similar to Fig. 5, of the same outside and inside measure as Fig. 5, but composed of pieces only one inch thick instead of two inches; and all of them two inches wide.

2. Draw a figure similar to Fig. 6, but let the upper pieces be only one inch thick (or high), and let them project each one inch at both ends beyond the lower pieces.

3. Draw a figure similar to Fig. 7 in position, but four inches wide and two inches thick—the wide side being in front.

4. Draw a figure similar in position to Fig. 8, but composed of three pieces, *each* twelve inches long, four inches wide, and one inch thick.

5. Draw Fig. 9 with the side in a plane fronting the spectator.

Free-hand Blackboard Exercises.—Figs. 5 to 10 inclusive—letting a space on the blackboard represent its true measure, two inches. In this case only *one half* of a diagonal measure will be required for a distance of two inches. In order to render the several surfaces distinct one from another, the dark shades may be represented by heavy vertical chalk lines, and the lighter shades by very light vertical lines. Or, where colored chalk crayons are accessible, the dark shades may be represented by blue lines.

Fig. 11, in its complete outline, is a cube eight inches square, having a small cube two inches square cut from each of its four upper corners. See the form of the entire cube, as represented by the dotted lines. What were the contents of the entire cube? What the contents after the four corners were taken out.

Fig. 12 is a cube twelve inches square, having a piece eight inches square and two inches thick taken from the centre of each of its three visible sides. What were the contents of the entire cube before the three pieces were taken out? What were the contents after these pieces were taken out? L
the pupil be careful, in drawing the figure, that his meas
shall be correct. Thus, the *depth* of the recess in each
must measure two inches. Thus *c d* and *m n* are meas

of two inches each; and *a b*, being one diagonal, is also a measure of two inches.

Fig. 13 represents a rectangular frame measuring ten by fourteen inches, and composed of pieces two inches square framed into posts two inches square and ten inches long.

NOTE.—To get the full effect of the figures on this page, view them from a point at the right and above them, through the opening formed by the partially closed hand. The pupil should be accustomed to view his drawings in the same manner.

PROBLEMS FOR PRACTICE.

1. Draw a figure similar to Fig. 11, but twelve inches square, having a block four inches square cut from each of its four upper corners.

What would be the contents of the entire cube? What the contents after the four corners were taken out?

2. Draw a figure similar to Fig. 12, but fourteen inches square, and showing a rectangular piece ten inches square and four inches in thickness cut from the centre of each of its three visible sides.

What would be the contents of the entire cube? What the contents after the three rectangular pieces were taken out.

3. Draw a figure similar in all respects to Fig. 13, except that the four horizontal pieces of the frame-work are to be only one inch in vertical thickness.

Free-hand Blackboard Exercises.—Figs. 11, 12, and 13; also the accompanying problems.

PAGE TWO.—SCALE OF ONE INCH TO A SPACE.

Fig. 14 represents a cube eight inches square; and Fig. 15 represents a box formed of one-inch stuff, open at the top, and of a size that will just receive the cube; so that the latter, when placed within the box, shall fill it even with the top. At *A* is the cover that will just fit the top of the box.

What is the size of the cover? Of the side *B* of the box? Of the sides *C C*? Of the bottom of the box? What are the outside measures of the box when the cover is on it?

Fig. 16 represents a series of five blocks placed one upon another, and rising in the form of stairs. The upright piece in a stair (as *a*) is called *the riser*, and the part on which the foot is placed (as *b*) is called *the tread.* In Fig. 16 the stairs are so placed that the risers front the spectator; but in Fig. 17 the side of the stairway fronts the spectator, and the riser is viewed diagonally. Fig. 17 measures the same as Fig. 16, with the exception that in Fig. 17 the lower block is omitted.

If these two figures are supposed to be drawn to a scale of four inches to a space, what will be the height of each riser, and the width of each tread? What the width of the stairway?

Fig. 18 represents a cabinet frame-work formed of pieces two inches square at the ends; the whole frame measuring ten inches by twenty-six. Here the longest side fronts the spectator; but in Fig. 19 the same frame-work is represented with the *end* fronting the spectator. Observe that the end below *c d* of Fig. 18, which is there seen diagonally, is not seen at all in Fig. 19; and that the end below *a b* of Fig. 19 is not seen at all in Fig. 18. Let the pupil describe the several pieces of which the frame-work is composed.

Fig. 20 represents a cross made of pieces measuring, at the ends, two by three inches.

Fig. 21 represents a cabinet square made of one-by-two-inch stuff, and placed horizontally; but, as the spectator is supposed to be above and to the right of it, one of the arms seems to rise at an angle of forty-five degrees—being in the diagonal direction of the small ruled squares.

Fig. 22 represents the same cabinet square in a vertical position, and so placed that the wide side shall front the spectator. The former, as placed, is a measure for horizontal and diagonal distances; the latter, for horizontal and vertical distances.

Fig. 23 is an upright frame-work resting on four blocks, each two inches square; having only two of its sides and the top and bottom inclosed, and containing three shelves in addition to the top and bottom. Let the pupil describe this frame-work more fully; and tell (or write out) its measures in all its parts—distances apart of the shelves, etc. The whole on the supposition that it is drawn to the scale of one inch to the space.

The *shading* on this page is supposed to be done, first, with India ink; some of the sides are then shaded with lines by the pencil, which, when not too heavy, give additional life and spirit to the drawing.

PROBLEMS FOR PRACTICE.

As Fig. 14 represents a cube eight inches square, what are its contents in cubic inches? *Ans.* $8 \times 8 \times 8 = 512$ cubic inches.

As it takes 231 cubic inches to make a gallon, how many gallons of water would the box, Fig. 15, contain? *Ans.* 2 gallons and 50 cubic inches.

1. Draw a box, similar to Fig. 15, that would contain a cube twelve inches square; and draw the cover separately. How many gallons of water would such a box contain?

2. Draw a rectangular box open at the top, the bottom of which shall measure, on the inside, ten by twelve inches, and let the box be ten inches deep. How many gallons of water will it contain?

3. Draw a flight of stairs, similar to Fig. 17, to a scale of six inches to a space, and having the risers twelve inches high, and the tread eighteen inches wide.

4. Draw a frame similar to Fig. 18, but formed of stuff one by two inches —the one-inch being the height.

Free-hand Blackboard Exercises.—Figs. 17, 18, and 20, and problems 2 and 3.

PAGE THREE.—SCALE OF THREE INCHES TO A SPACE.

Fig. 24. At *A* is represented a piece of timber six by twelve inches at the end, and four feet long, broadest side down, having a piece cut from the centre of the upper side one foot square and three inches deep, to receive crosswise another timber cut in like manner. At *B* the two pieces of timber are united at right angles to one another.

The remaining figures on this page are examples of what carpenters call *scarfing*, which means the uniting of two pieces of timber longitudinally by a *scarf-joint*—in common language often called *splicing;* but the latter term is more properly applied to an overlapping joint that is not notched.

Fig. 25. At *C* and *D* are two pieces of timber prepared for being joined lengthwise by a square scarf-joint. After placing the timbers in the right position, they are pinned or bolted together. Let the pupil describe the two pieces.

Fig. 26. At *E* is the upper piece of timber, and at *F* the lower to be united by a scarf-joint, which is formed of the so[illegible]f-joint combined with the splice-joint. Observe

that the line of union, *2 4*, in both *E* and *F*, is in the direction of two-space diagonals; and as the two lines are of the same length, and the two timbers lie in the same relative positions, the cut sections must correspond with one another. Moreover, *E* and *F* are redrawn at *G* and *H*; and there it is seen that the diagonal line of union, *2 4*, is in both cases the diagonal of the same rectangle *1 2*, *3 4*.

Fig. 27 shows two pieces of timber, *I* and *J*, prepared for being joined by the ordinary splice-joint. The two timbers are to be firmly bolted together. But this is by no means so firm a mode of union as is shown in Figs. 25 and 26.

Fig. 28 shows a still firmer mode of the scarf-joint than Figs. 25 and 26. Observe that the lines of union in *K* measure precisely the same, and are in precisely the same positions, as in *L*. Thus the lines *1 2* and *3 4* are the same in length and position as the lines *5 6* and *7 8*, both being two-space diagonals.

Fig. 29 shows, perhaps, the firmest of all modes of the scarf-joint, especially for heavy timbers. *N* is the upper piece; and the two must be united by placing *M* and *N* side by side, and driving them together. Even then, without bolting, they can not be drawn apart lengthwise; nor, if the joints be good, can they be easily sprung in any direction. At *X* the two pieces are shown as they appear when united.

Fig. 30 represents the same pieces that are shown in Fig. 29; but here drawn in a different position, being placed sidewise toward the spectator, instead of endwise toward him as in Fig. 29. Observe that the measures, according to the scale, are the same in the one case as in the other. That mode of representation which will give the best view of the object should in all cases be adopted; and in some cases both modes should be used, as the one will often give views of parts that are not shown in the other.

Fig. 31 shows a still different mode of scarfing, and one that is very firm, and much more easily executed than Fig. 30. When the pieces are firmly bolted together, the interlocking gives them great additional strength against any force that might tend to wrench them sideways.*

PROBLEMS FOR PRACTICE.

1. Draw *A* of Fig. 24 with the narrow side toward the spectator.
2. Draw the two parts of Fig. 25 with the narrow sides toward the spectator.
3. Draw Fig. 28 with the dark sides of both pieces toward the spectator.
4. Design a figure similar to Fig. 30, but of different proportions in the interlocking parts.
5. What are the contents of *A*, Fig. 24; the scale being three inches to a space?
6. What are the contents of the entire Figure *B*?

Free-hand Blackboard Exercises.—Any or all of the figures on page 3.

PAGE FOUR.—SCALE OF TWO INCHES TO A SPACE.

This page shows the different methods adopted by masons and engineers in laying bricks. A brick of ordinary size is two inches thick, four inches wide, and eight inches long. Bricks which are laid lengthwise across the wall, with their ends toward the face of the wall, are called *headers;* and those which are laid with their lengths parallel to the face of the wall, are called *stretchers.* The two principal methods of laying bricks in walls, where much strength is required, are what is called the *English bond* and the *Flemish bond.* In the former, the face of the wall always shows the headers and stretchers in alternate layers, or *courses*, as they are called by bricklayers. Thus at *A* is a course of *headers*, and at *B* is a course of *stretchers;* and in English bond the *face* of the wall shows alternate courses of the two. For *Flemish* bond, however, the face of *each course* is composed of a combination of headers and stretchers. In both, a brick of half the ordinary width, and also one of half the ordinary length, is often required; and these half bricks should be made in every brick-yard.

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* It may here be remarked that the only lines in Diagonal Cabinet Perspective which are susceptible of *direct* measurement are the horizontal, vertical, and diagonal lines; and that when any other line occurs, if it is to be measured, it must be done by mathematical calculation, after first resolving it into the hypothenuse of a right-angled triangle. Thus at *G* the lines *2 1* and *1 4* are measurable; the former, according to the scale here adopted, measures nine inches, and the latter thirty-six inches; and the angle *2 1 4* represents a right angle. Hence the line *2 4* is the hypothenuse of a right-angled triangle; and the teacher may show the advanced pupil how to ascertain its precise length by adding together the squares of the sides *2 1* and *1 4*, and then extracting their square root. And so in all similar cases of the measurement of lines that are neither diagonal, vertical, nor horizontal.

Fig. 32 represents a wall eight inches thick, laid in English bond. Observe that the first or upper course is composed of headers; the second of stretchers; the third of headers; the fourth of stretchers, etc. In drawing these examples (as in nearly all other cases of drawing), it is necessary to draw the upper portions first—that is, to begin at the top.

Fig. 33 represents a twelve-inch wall in English bond. Observe that the *face* of the wall shows alternate courses of headers and stretchers; while each course is composed of both kinds, arranged in a peculiar order, as shown in the drawing.

Fig. 34 represents a sixteen-inch wall in English bond. The *face* is the same as in the eight and twelve inch walls. The upper two courses show the arrangement.

Fig. 35 represents an eight-inch wall in *Flemish* bond; showing that each course is composed of both headers and stretchers.

Fig. 36 represents a twelve-inch wall in Flemish bond. Here half bricks of both kinds are used.

Fig. 37 represents a sixteen-inch wall in Flemish bond.

Fig. 38 represents what is called English *cross bond.* Here the face of the wall shows an arrangement in the second stretcher line by which its joints come exactly below the middle of the bricks in the first stretcher line; and the same arrangement of stretchers comes back every fifth line. By comparing Fig. 38 with Fig. 32 the difference will be manifest.

Fig. 39 represents a twenty-four-inch wall laid in Flemish bond, on the farther half of which rises a twelve-inch wall in English bond, both halves being capped with twelve-by-twelve-inch stones two inches thick. There are also two triangular abutments resting on the front half of the lower wall, and abutting against the upper wall. These abutments are twelve inches high at the back, and their bases project forward twelve inches, the width of the lower half of the wall. Their faces, therefore, are laid at an angle of forty-five degrees; and hence each layer of stones, of which the abutment is composed, although only two inches thick, presents a much greater front surface view. The teacher may require of the advanced pupil the length of the face of the abutment, as designated by the line *2 3* or *4 5*. See Note, page 94.

PROBLEMS FOR PRACTICE.

1. Draw an eight-inch wall in English bond, forty inches in length at the base, and showing three partial courses and four full courses.

2. Draw a twelve-inch wall in English bond, forty-eight inches in length at the base, and showing four partial courses and four full courses.

3. Draw a twelve-inch wall in Flemish bond, fifty-six inches in length at the base, and showing four partial courses and four full courses.

4. Let the pupil design a twenty-inch wall in English bond, and also a twenty-inch wall in Flemish bond, and so that the bricks will break joint in the best manner possible.

Blackboard Exercises.—Any of the figures of page 4, showing the true size of the bricks.

PAGE FIVE.—SCALE OF TWO INCHES TO A SPACE.

Fig. 40 represents a cross-shaped figure formed by so cutting a cube twenty inches square, that vertical sections, eight inches square at the ends, are taken away from its four corners. The form and extent of the entire cube are shown by the dotted lines. Let the pupil calculate the number of cubic inches taken away, and the number remaining.

Fig. 41 represents a cube of the same original size as Fig. 40, from which several sections are cut away, leaving what is shown in the figure. Let the pupil calculate the number of cubic inches taken away, and the number remaining.

Fig. 42 shows, on its front vertical face, a single fret of the same form as is seen at Fig. 24, page 6, of Book No. I.; but here, in Fig. 42, the fret is shown, not as a surface decoration merely, but in the solid form, four inches in thickness.

Observe that the thickness is represented by one diagonal space.

Fig. 43 shows the same solid fret, but with the addition of a solid piece four inches square running through it centrally, the two being framed together.

Fig. 44 represents a frame-work thirty-four inches wide and fifty-six inches long, the side pieces formed of timbers six inches square at the ends, and the end pieces formed of timbers six by sixteen inches at the ends, the end pieces being mortised into the side pieces by tenons two inches thick, eight inches wide, and six inches in length. Hence the mortises which receive the tenons must extend entirely through the timbers. At *A*, *B*, *C*, and *D*, the four timbers which compose the frame are drawn separately, and in their relative positions; and at *F* they are put together. The side pieces show mortises for upright posts. At *E*, one of the end timbers is represented as standing vertically on one of its tenons, with its broadest side fronting the spectator. Observe that, according to the scale, it measures precisely the same as *C* or *D*.

PROBLEMS FOR PRACTICE.

1. Draw the lightly dotted outlines of a cube of the same dimensions as Fig. 40; and then represent the cube as it would be after taking vertical sections from its four corners, and from the centres of its four sides, each four inches square at the ends. First mark out, on the upper face of the dotted cube, the upper face as it would appear after the pieces were taken out. What would be the solid contents of the eight pieces thus taken out? The solid contents remaining in the cube?

2. Draw a fret similar to Fig. 34, page 6, of Book No. I., representing the solid form of the fret, two inches in thickness; but draw it on an enlarged plan, so that the width of the fret-line shall occupy a full space. Scale, two inches to a space.

3. Draw *F* of Fig. 44 so that the longest side shall front the spectator.

4. Draw the same frame standing on one end, with the broad side fronting the spectator.

5. Draw the same frame standing on one end, with the *edge* of the frame fronting the spectator.

Blackboard Exercises.—Any of the figures and problems on page 5.

PAGE SIX.—SCALE OF TWO INCHES TO A SPACE.

Figs. 45 and 46 represent the same frame-work, but placed in different positions in relation to the spectator; and Fig. 47 represents these two frames united by string-pieces, in the form of a bedstead. Let the pupil give the dimensions, according to the scale adopted for the page—two inches to a space.

Fig. 48 represents a vertical pillar twelve inches square, surrounded at the top by a moulding four inches in height and projecting four inches. Observe that the projection of the moulding, whether measured horizontally by the distances *1 2* and *5 6*, or diagonally by the distances *2 3* and *4 5*, etc., is in all parts four inches. The *height* of the pillar is the distance *2 9*, which is twenty inches. Observe the following rules: 1. *A horizontal moulding, or any horizontal projection, conceals from view a portion of the front vertical surface immediately below it, equal in height to one half the projection.* Thus the dotted line *7 8* indicates the lower line of the attachment of the moulding to the front face of the pillar; by which it is seen that the moulding, *four* inches in projection, conceals from view the *two* inches in height of the front face of the pillar immediately below the attachment of the moulding. This principle is also seen in the fact that the distance from the base of the pillar to the moulding is measured from 9 to 7—thus making the moulding sixteen inches above the base. 2. *A horizontal projection conceals from view a portion of the* DIAGONAL *vertical surface immediately below it, equal in height to the extent of the projection.*

Thus *8 12* is the line of the attachment of the under side of the moulding to the side of the pillar; and *12 13* shows the vertical extent of the side of the pillar which the moulding conceals.

But suppose the front moulding did not project at all beyond the face of the left-hand side of the column. It will be seen that, in that case, the front end of the moulding would terminate in the line *3 10*; thus having an apparent projection of two inches beyond the line *7 9*, the same as the right-hand end of the moulding would seem to project to the left of the line *8 11*. All the principles of the projections of rectangular mouldings may be learned from this figure.

Fig. 49 represents the same pillar, twelve inches square, and the same moulding as in Fig. 48; but in Fig. 49 the moulding is placed six inches below the top. Observe that the measurements of the projection, and of the parts concealed, are the same in both figures.

Fig. 50 represents the same pillar as in the preceding two figures; but here it is placed upon a base four inches thick, that projects beyond the four faces of the pillar four inches on all sides. Observe how the measurements are made here also.

Fig. 51. Here we have represented eighteen inches in height of the top of a pillar which is twenty inches square at the ends, with a projecting moulding of four blocks on a side, four inches apart, encompassing the upper end of the pillar. These blocks are each four inches in height and two inches in thickness, and have a projection of four inches. In drawing them, first trace lightly a moulding around the pillar, similar to the moulding of Fig. 48; then mark out, in this moulding, the divisions which constitute the blocks. Observe that the blocks on the two diagonal sides of the pillar must necessarily be only half a diagonal in thickness to represent two inches. Notice the portion of the face of the pillar below the blocks concealed by their projection.

Fig. 52, which represents a pillar resting upon a block that projects four inches from the face of the pillar, has a narrow moulding one inch thick, with a projection of two inches, encompassing the pillar near the middle of its height. How far is this moulding below the top of the pillar, and how far above the top of the projecting base?

Fig. 53 represents a four-legged table, placed bottom upward, so that its several parts may be shown in the best manner possible. They could not be seen so well if it were represented in its natural position. Let the pupil describe the size and length of the legs—how they are placed in relation to the inclosing frame; width and thickness of this frame, length of its sides, and how joined at the corners; size of the top of the table, its projection beyond the frame, thickness and number of the boards which compose it, etc.

Fig. 54 represents a diamond or lozenge-shaped figure formed of two-space diagonals, and having a thickness of four inches. What is its length? Its breadth? Its front-face measure in square inches? (See page 58; No 7.) Its contents in cubic inches?

Fig. 55 is the same figure as 54, but its length is here placed in a front vertical position.

PROBLEMS FOR PRACTICE.

1. Represent a vertical piece of timber twelve inches square at the ends, and twenty-four inches in height, surrounded by a moulding even with the top, two inches in height, and projecting four inches; also a like moulding even with the base of the timber. Be careful to get the correct height of the timber, as portions of the top and bottom are concealed by the moulding.

2. Make a drawing like Fig. 47, with the exception that the posts shall rest upon a frame formed of stuff four inches thick and four inches in width, and that a frame formed of stuff four inches in width and one inch in thickness (or height) shall rest upon the tops of the posts. Be careful to trace the outlines very lightly at first, and only mark them firmly when the visible portions are correctly represented.

3. Draw a lozenge whose front face shall be like Fig. 54, but whose diagonal length shall be twelve inches.

4. Draw the same lozenge twelve inches in diagonal length, but in the position of Fig. 55.

Blackboard Exercises.—Figures 47, 48, 49, and the foregoing problems.

PAGE SEVEN.—SCALE OF FOUR INCHES TO A SPACE.

All the figures on this page, except Fig. 64, contain some lines that are neither true diagonals, verticals, nor horizontals; yet their positions are as accurately defined as the positions of those lines that are directly measurable.

Fig. 56 represents a kind of heavy block table, thirty-two inches in height, having its top surface thirty-two inches square, and resting on a base thirty-two inches square. The base bevels upward, and the top bevels downward to the same extent. As the line *a b* is drawn *diagonally* from the corner *a*, thirty-two inches, so must the line *c d*, drawn from the corresponding corner *c*, run diagonally in the same direction; and its real length is thirty-two inches, but the farther eight inches are not visible. It is best to draw the top first; then the front face; then the diagonal lines.

Fig. 57 represents the same block table, with the exception that the vertical section, eight inches in length, is cut out of the centres of both sides of the base. Observe that as the distance *i f* is eight inches, so must the distance *g a* be eight inches also; and that *a b* must run toward the point *c*, which is a point on the left-hand side of the table corresponding to *d*. And *c* and *d* must be the same distance apart as *n* and *m*.

Fig. 58 is the same as Fig. 57, with the exception that the section cut out here extends through the entire central support; and Fig. 59 shows the same as Fig. 58, with the top removed.

Figs. 60, 61, 62, and 63 are the same as the figures directly above them, with their sides turned to the front. Observe that Fig. 60 measures in all respects, according to the scale, the same as Fig. 56. Thus the dotted vertical lines in the base front of Fig. 56, although seen in a side view in Fig. 60, are in the latter, as in the former, the downward continuation of the columnar support, and in both cases are eight inches apart, eight inches in length or height, and at the same distances from the corners *a* and *c*. And if the length of the line *a o*, in Fig. 60, should be calculated mathematically, it would be found to be of the same length as the same line *a o* in Fig. 56. Let the pupil trace out the like measurements in Figs. 61, 62, and 63, with the figures above them.

Fig. 64 represents a heavy frame-work sixteen inches in height or thickness, and seven feet four inches square, with a vertical recess of twelve by forty inches in the centre of each of its four sides, and a vertical opening forty inches square through the centre of the frame.

Fig. 65 represents the same frame-work as Fig. 64; but in place of the square opening in the centre, there rises, above the frame-work in Fig. 65 a four-sided pyramid, forty inches square at the base, and thirty-six inches in vertical height. Observe that the outlines of the base of the pyramid are the same as the upper surface outlines of the square opening in the centre of Fig. 64, and are represented by the same figures, *1*, *2*, *3*, *4*, in both cases. The centre of the base of the pyramid, it will be seen, must be the point *9*—the point of intersection of the lines *5 6* and *7 8*, which connect the centres of opposite sides of the base. The vertical height of the pyramid above the base must therefore be the length of the line *9 10*, which represents a line drawn vertically upward from the centre of the base to the apex of the pyramid.

PROBLEMS FOR PRACTICE.

1. Draw a figure similar to Fig. 56, but forty-four inches square at the bottom and top; and with the central vertical support twenty inches high from *o* to *x*, and only four inches in thickness.

2. Draw the same with the side view brought in front.

3. Draw a figure whose base shall be similar to that of Fig. 65, but whose extreme side measures from corner to corner shall be six feet, and the height or thickness eight inches; the recesses on the centres of the sides sixteen by twenty-four inches; the base of the pyramid twenty-four inches square, and its vertical height fifty inches.

Blackboard Exercises.—Figs. 56, 57, 58, and 62. Also draw Fig. 65, giving to the frame-work one half the measures denoted on the paper; but make the pyramid thirty-six inches in vertical height. The dark shades may be designated by heavy vertical lines, with either blue or white crayons.

PAGE EIGHT.—SCALE OF ONE FOOT TO A SPACE.

Fig. 66 may be supposed to represent a block of stone twelve feet square, and four feet in height or thickness. Suppose that we wish to place, centrally, on the top of this block a four-sided pyramid, eight feet square at the base, and fifteen feet in vertical height from the top of the base.

Evidently the base of the pyramid will be, on all sides, two feet within the outlines of the top of the base on which it rests. The lines *a b*, *b f*, *f d*, and *d a*, representing the outlines of the base of the pyramid, must therefore be drawn two *horizontal* spaces within the upper side lines *i m* and *n j* of the base, and one *diagonal* space within the front and back lines *i n* and *m j*. The centre, *c*, of the base of the pyramid, must evidently be at the intersection of the central lines *o p* and *h g*, and these lines will be sufficient to designate it; but it must also be at the intersection of the diagonal lines *a f* and *d b* of the base. The apex of the pyramid must be vertical to the point *c*.

Fig. 67. The top of the base of this figure is the same as the top of the base drawn in the preceding figure, and on this base the pyramid, of the same dimensions as that designated for Fig. 66, is placed. The dotted lines and the letters are put in to designate the same points that are given in Fig. 66. Observe that the point *x*, the apex or *vertex* of the pyramid, is taken fifteen spaces vertically above the centre, *c*, of the base; and from *x* lines are drawn to the corners *d*, *f*, and *b*. The fourth corner-line of the pyramid extends from *x* to *a*, but it can not be seen because it is on the side opposite to the spectator. The line *c x* is called the *axis* of the pyramid.

The base of Fig. 67 is represented as ten feet in height and twelve feet square; and it has recesses in the centres of its sides six feet high, eight feet wide, and two feet in depth.

Fig. 68 is a wedge-shaped pyramid, eight feet square at the base, and eleven feet in vertical height. Observe how the edge, *a b*, of the pyramid is drawn so as to be directly above the central diagonal line, *g h*, of the base.

Fig. 69 is the same as Fig. 68; but the side view of the wedge is here brought in front of the spectator. Observe that the measurements are the same in both cases. See the height, *a g*, in both.

Fig. 70 has the same base, eight feet square, and the same height, eleven feet, as the preceding two figures; but the wedge-shaped pyramid is diminished to four feet at the apex. If the edge of the pyramid were the line *a b*, the figure would be the same as Fig. 68; but the edge is diminished two feet at each extremity by cutting off *a r* and *s b*.

Fig. 71 is a truncated pyramid—the top being cut off parallel with the base. Its vertical height is the axis line *c d*. The lines forming the edges of the sides are drawn toward a point in the upward extension of the line *c d*.

Fig. 72 represents the top of a pillar in the obelisk form—

the top being cut off in the form of a flat pyramid. The vertex, *x*, must be in the line of the axis of the pyramid. If the sides of the block were vertical, we might suppose its base to be *g*, *d*, *i*, *n*, in the figure below it; then *c x* would be the central line or axis.

Fig. 73 represents an obelisk, which consists of an upper pyramidal part, *D*, called the *shaft*, and the support or base on which it rests, called the *pĕd'estal.* The pedestal is divided into three parts: *A*, the base; *B*, the die; and *C* the cornice. There is often a recess, or sunken part, in the die, which contains the inscription, etc. The vertical height of the shaft of Fig. 73 is seen to be twenty-seven feet, by counting the spaces from *n* to *x*, which line is the axis; and the base of the shaft is eight feet square. The entire vertical height of the pedestal—from the bottom of the base to the top of the cornice—will be found to be eleven feet, as measured from *m*, the centre of the bottom of the base, to *n*, the centre of the top of the cornice. The point *m* must be at the intersection of the lines which connect the opposite corners of the bottom of the base. The face of the die is seven and a half feet in height and eight feet wide; and the recess in its centre is five and a half feet in height, and six feet wide, so that the recess is just one foot within the edges of the die. As the cornice projects one foot, it conceals from view just *one half* of a foot of the upper part of the front face of the die, and *one foot* of the upper part of the side face (see Rules, page 98); hence the upper line of the recess on the right side of the pedestal coincides in view with the bottom line of the cornice. The recess in each of the sides of the shaft is also one foot in depth. The side corner-lines of the shaft are drawn toward a point directly above *x*, in the continuation of the axis. The upper extremity of the shaft is in the flat pyramidal form, similar to Fig. 72, but more pointed.

Fig. 74 is a Grecian fret, the same as Fig. 25 on page 6 of Book No. I., here changed into the solid form; and Fig. 75 is the same as Fig. 26 on the same page of Book No. I., here changed into the solid form. In both cases the thickness of the fret, diagonally, is the same as the width of its front face.

☞ To get the full effect of the drawings on this page, view them as directed on page 50. Let the pupil view his own drawings in the same manner.

PROBLEMS FOR PRACTICE.

1. Draw a base and pyramid similar to Fig. 67, but let the base be a cube ten feet square; let the pyramid be placed one foot within the outlines of the top of the base, and let the vertical height of the pyramid be eighteen feet. Let the recesses of the base be only one foot deep, and a foot and a half from the edges of the sides.

2. Draw a wedge-shaped pyramid, similar to Fig. 68, whose base shall be ten feet square, and whose vertical height shall be sixteen feet.

3. Draw an obelisk of the following dimensions: 1st. The pedestal: *base*, fourteen feet square, and three feet in thickness; *die*, ten feet square at its base, and height twelve feet; recess in die two feet from edges, and one foot in depth; *cornice*, a foot and a half in thickness, and projection beyond the face of the die one foot. 2d. The shaft: base of shaft eight feet square, placed centrally on the cornice; vertical height thirty feet, and apex like Fig. 72.

4. Draw a fret like Fig. 75, with the exception that the face of the bands, as seen in front, shall be only six inches wide, and the bands eighteen inches apart, while the diagonal depth or thickness of the band shall be two feet.

Blackboard Exercises.—Draw and shade the frets, Figs. 74 and 75, on the supposition that the ruled lines on the blackboard are one foot apart.

PAGE NINE.—SCALE OF TWO INCHES TO A SPACE.

Fig. 76 represents a post-and-board fence, its *length* being here viewed diagonally, with what is called the *inside* of the fence exposed to view, so as to show its construction. The posts are eight inches square, and twenty-six inches above ground; rails two by four inches, the lower one let into the posts, and the upper one resting on the posts, both flush with the front edge of the posts; boards thirty-four inches in height, one inch thick, and eight inches wide, except the two end boards, which are only four inches wide. In the drawing the posts are placed, for want of room on the paper, much nearer together than they would be in the real fence.

Fig. 77 represents the same fence that is shown in the preceding figure; but here its length is placed fronting the spectator, and the *end* is viewed diagonally. Let the pupil test the measurements of both figures, and see if in all respects they fully correspond with each other.

Fig. 78 is a somewhat elaborate post-and-rail fence. Here the posts are eight by twelve inches in size, and thirty-two inches in height; and the rails are two by four inches, the lower three rails being let into the posts four inches. Let the pupil describe the construction in full—length, position, distances apart, etc., of all the rails.

Fig. 79 represents a four-pointed star cut out of a plank two inches in thickness. Let the pupil describe it: distance of the points from the centre, etc.

PROBLEMS FOR PRACTICE.

1. Let the pupil draw a fence similar to Fig. 76: posts to be six inches square; rails two by three inches; height of posts and length of boards the same as in the figure.

2. Let him draw the same in the position represented in Fig. 77.

3. Let him draw Fig. 78 so that its *length* shall be viewed diagonally. It will be found that some objects can be best represented in one position and some in another.

Blackboard Exercises.—Fig. 76, and problem 2.

PAGE TEN.—SCALE OF TWO INCHES TO A SPACE.

Fig. 80 is another form of post-and-rail fence, in which the rails, in their full size of two by four inches, are mortised through the posts—the top of the rail being in a horizontal position. Let the pupil describe the posts, rails, etc., in full. The posts are here drawn much nearer together, according to the scale, than they would be placed in the real fence.

Fig. 81 will illustrate the principles of drawing the representation of a fence where the square rails are let into the posts *diagonally.* Let the upright timber here represent the post, which, however, is here drawn, for convenience of representation, only two inches in thickness, and twenty inches in width. Suppose we wish to represent a diagonal square mortise through this post, for the purpose of receiving a square rail of twelve inches *diagonal* diameter. Lay off the square *1 3 5 7*, of twelve inches to a side, and square with the ends and sides of the post. Mark the middle points in the sides of this square, and connect them, measuring twelve inches from *8* to *4*, and the same from *2* to *6*, and we shall have the diagonal square *2 4 6 8.* Represent this square as cut through the post, and we shall have the appearance of the diagonal square mortise which is to receive the rail placed in a diagonal position. Observe that the lines *2 8* and *4 6* are drawn in the direction of three-space diagonals. Below we have the appearance which would be presented by the rail passing through the post. The rail is so placed, with reference to the eye of the spectator, that one side of it appears very wide; while the other side, being seen very obliquely, appears very narrow.

At *A* we have represented the posts of the same size as in Fig. 80, with the square rail passing through them diagonally.

At *B* we have represented the side of the post through which the rail passes as fronting the spectator—as it would be drawn if the fence were viewed diagonally lengthwise. In this case the diagonal square mortise would be well represented, but only *one side* of the rail would be seen, as indicated by the dotted representation of it. Hence the diagonal lengthwise representation of such a fence would not be a good one.

Fig. 82 is still another form of post-and-rail fence, which the pupil may describe.

Fig. 83. In this figure the cross-beam, which is supposed to be designed to sustain a heavy weight, is supported by two braces, which are framed into the cross-beam and also into the posts. The under side of the brace on the left is seen so obliquely that it exposes to view only a very narrow surface.

Fig. 84 is the same pattern of the quadruple or four-band fret that is used for the setting of an Arabian mosaic in Fig. 43, page 7, of Book No. I. Here, in Fig. 84, the fret alone is given, and in the solid form. In the lower part of the figure the *half* diagonal lines are marked in, to show the method of representing the thickness of the fret. Each of these lines, it will be seen, is drawn in a diagonal direction, and the length of half a diagonal. Understanding this, the whole figure is very easily executed after the original fret has been drawn.

[illegible]

[illegible] square [illegible] [illegible] [illegible] edges of the [illegible] [illegible] [illegible]

[illegible] [illegible] figure.

[illegible] — [illegible]

[illegible]

[illegible]

[illegible] [illegible] [illegible] [illegible] drawing.

[illegible] eight inches square at [illegible] and twenty inches in length, having its ends [illegible] resting upon two vertical pieces of [illegible] fifteen inches square and two inches thick.

Fig. [illegible] the Grecian [illegible] fret represented in Fig. [illegible], *page* [illegible], *of Drawing-Book No.* I., but here drawn to a larger scale and put into the solid form. Observe that the bands [illegible] the same in width, and the same distance apart. Observe [illegible] that the short corner diagonal [illegible] drawn to the *centres* of the small squares; and [illegible] measure the required thickness of the [illegible] the *correct* diagonal direction for the solid.

[illegible] a Grecian double fret, of the kind seen on *page* [illegible], *of Book No.* I., *Fig.* 12. It is here put into the solid [illegible], and [illegible] for the bordering of a tablet, which is supposed to be ornamented.

Fig. 89 represents a heavy plank chest, thirty-six inches square on the bottom, and twenty-one inches in height when the lid is closed. In the top of the chest is placed a tray, having in it nine partitions. This tray rises three inches above the body of the chest; but its partitions are only two inches deep; and when the lid shuts down it incloses within it the three inches' elevation of the tray. Let the pupil examine and test all the measurements, and see if the lid will accurately fit over the tray, and also be even with the outside of the chest. What is the thickness of the top of the lid?

PROBLEMS FOR PRACTICE.

1. Draw the representation of a board-picket fence: rails the same as in Fig. 85, but the pickets two inches wide, twenty inches long, made of stuff two inches thick, and placed four inches apart.

2. Draw the representation of a chest similar to Fig. 89. Suppose it to be thirty-eight inches square; the body sixteen inches high; top five inches high, made of stuff two inches thick; but *the tray* made of one-inch stuff, and rising three inches above the body. Divide the tray into sixteen square divisions, each eight inches square (*including* the partitions); and let the partitions be three inches deep. Place the cover on the farther side, *opposite* the front.

Blackboard Exercises.—Figures 85 and 87, and problem 1.

PAGE TWELVE.—SCALE OF SIX INCHES TO A SPACE.

Fig. 90 represents a solid octagonal block, five feet in length, with a face diameter, on the line *1 2* or *3 4*, of three feet. The octagonal form is the same as that of No. 13, page 2, of Book No. I. Observe that, in drawing the visible sides of the block, we draw *diagonal* lines from the points *5*, *1*, *6*, *4*, and *7*, and in all cases a distance of five diagonals, representing five feet.

It will be easy to find the solid contents, in cubic inches or feet, of such a block, after the directions for measuring surfaces given in the preceding book. Thus, on the scale of six inches to a space, the front face of Fig. 90 measures six square feet; and as the length of the block is five feet, the contents of the block must be five times six, or thirty cubic feet.

Fig. 91 has the same front face as the star figure contained within the No. 13 just referred to, or the same as the star figure No. 11 of Lesson VI., on the same page. As the face of the star form, Fig. 91, contains an area, according to the scale, of two square feet, and as the length of the solid is six feet, the solid contents of Fig. 91 would be twelve cubic feet.

Fig. 92 is a hexagonal, or six-sided solid, six feet in length, its two parallel ends being formed of hexagons. The pupil can now, doubtless, easily calculate the cubic contents of this figure.

Fig. 93 is an octagonal figure, of the same front outline as No. 10 of Lesson VIII., page 2, of Book No. I. Six inches within the series of the outer front lines is another series, whose distance from the outer lines is regulated by the points *1*, *2*, *3*, *4*. Both the outer and the inner lines are drawn in the direction of three-space diagonals. This completed figure forms a hollow octagonal tube, one foot in length, whose sides are six inches in thickness, with an extreme diameter, both vertical and horizontal, of four feet. The points *5* and *6*, one diagonal space distant from *4* and *3*, regulate the drawing of the inner boundary-lines of the farther end. These lines also are drawn in the direction of three-space diagonals, and are hence parallel to their corresponding front lines.

Fig. 94 is a solid octagonal block, of four feet vertical and horizontal diameter, and six feet in length. The pupil, referring back to Book No. I., should now be able to calculate its cubical contents. Observe that the shading is such as most clearly to distinguish the several visible sides of the block.

Fig. 95. The outline of the front face of the block here represented forms a dodecagon, or figure of twelve sides, the same as is shown on page 2 of Book No. I.; while the hollow or opening through the block is hexagonal. It is easy to see how the lines bounding the several sides of the block lengthwise, both on the outside and inside, are to be drawn —all in the direction of diagonals. The outside lines must all, of course, be of equal length; and the lines forming the boundary of the farther face of the dodecagon must be parallel to those forming the boundary of the front face. But they are made parallel with perfect ease, because their position and limits are definitely designated by the ruling of the paper.

Let the pupil, referring back to the outlines of the same dodecagon on page 2 of Book No. I., calculate the solid contents of Fig. 95.

Fig. 96 has the same front face as Fig. 95, but the solid formed upon it is only one foot in length. It is thus drawn in order to show a portion of the inner outlines of the farther end of the block. What are the cubical contents of this figure?

Fig. 97, having the same outline front form as Fig. 90, is drawn to inclose an area four times as large as Fig. 90. (See ELEMENTARY PRINCIPLE, page 54.) This figure is a hollow octagon, two feet in length, and having its sides six inches in thickness. Observe that the front outline is formed by drawing *two-space* diagonals throughout; observe, also, that the *inner* boundary-lines of the octagon, at both ends, are the same in direction, but necessarily of less length.

Fig. 98 has the same outline front form as Fig. 93, but is drawn to inclose an area four times as large as Fig. 93. (See ELEMENTARY PRINCIPLE, page 54.) It is drawn of *three*-space diagonals instead of *two.* Observe how easily and accurately in all these figures the inside lines of the front face of the octagon are drawn, so as to be exactly parallel to the outside lines. Thus, after taking the point *1*, in Fig. 98, the line *1 7* is drawn in the direction of a three-space diagonal until it intersects the diagonal line *7 10;* then the line *2 7* is drawn as a three-space diagonal, and it will intersect the diagonal *7 10* in the point *7*. In like manner all the front inner-face lines are drawn. Observe, also, that the points *6* and *5* are designated by being three diagonal spaces distant from *3* and *4*. Then *6 12* and *5 12* are drawn in the direction of three-space diagonals, meeting in the same point, *12*.

Fig. 99 is a frame-work which requires little explanation. Observe that the braces must start at equal distances from the vertical post; and that the distance *1 2* must be the

cubic contents of Fig. 92, and whose front face shall contain four times the area of Fig. 92.

4. Draw a dodecagon hollow body, the extreme outline of whose front face shall be the same as Fig. 95: let the sides of the hollow body be of the same length, but only half the thickness of the sides of Fig. 95.

5. Draw a figure the same as Fig. 99, with the exception that the side shall *front* the spectator, and the platform base shall be one foot wider than there represented.

6. Draw Fig. 100 of the same dimensions as given, but with the side fronting the spectator.

[illegible]

[illegible]

[illegible] representations of [illegible] receding from the [illegible] of the object [illegible] actual form and pro-portions [illegible] supposed to be in a vertical position. [illegible] side of the cube in [illegible] Fig. [illegible] square. To an [illegible] spectator a drawn [illegible] supposed to be in a vertical po-sition. [illegible] represent a cylinder in [illegible] the end fronting the spectator [illegible] in natural form [illegible]

[illegible]

[illegible] a circle, with a radius [illegible] It may therefore represent the end of [illegible] diameter.

[illegible] the centre of the end of a [illegible] A *cylinder* is a solid whose [illegible] at right angles to the [illegible] passing through [illegible] at right angles to the ends of the [illegible] of a circle is often called its periphery [illegible] we speak of the *periphery* of a cylinder.

In Fig. [illegible] suppose the cylinder to be ten inches in [illegible] a line [illegible] drawn diagonally from the front centre, *c*, will represent the axis of the cylinder; and *c* will be the central point of the near end, and *d* the central point of the farther end. If, therefore, we describe a circle from the point *d*, with a radius of five inches, this circle, only one half of which could be seen in the solid cylinder, would give the true form and position of the farther end of the cylinder. Connect the extreme edges of these circles by the lines *p r* and *m n*, and we have all the visible outlines of the cylinder.

Fig. 3 is the same as Fig. 2, with the cylinder shaded, so as to represent it in its solid form. Observe here that *d*, the same as in the preceding figure, five diagonal spaces from *c* (ten inches), is the centre from which the visible boundary of the farther end of the cylinder is described. From points in the line *c d* are to be described the several circular bands which encompass the cylinder; and these bands will be the same distances apart as are the centres from which they are described.

Fig. 4. Here a longitudinal right-angled section, embracing one quarter of the cylinder, is taken away. This shows the position of the axis, *c d*, better than it can be seen in the preceding two figures. From the centre, *d*, are described, with the compasses, the visible portions of the farther end of the cylinder. The sides are drawn in the same manner as in Fig. 3.

Fig. 5 represents a cylinder of the same size, originally, as in the preceding three figures, but having, first, one quarter cut away, as in Fig. 4, and then, in addition, all but the lower left-hand quarter of the middle section is taken away. Measurements of the several sections may be made on the vertical, horizontal, and diagonal lines in the same manner as in all plane solids.

Fig. 6. Here, also, the cylinder is ten inches long, as measured on the line of its axis, *c d*. The upper *half* of the front portion, four inches in length, is first taken away; then a portion of the farther part, but less than a quarter, is removed.

Fig. 7 is the same as Fig. 6, but shaded so as to show the several parts more distinctly.

Fig. 8 represents three quarter-sections of a cylinder five inches in diameter and four inches long.

Fig. 9 represents a cylinder four inches in length and ten inches in diameter, with an opening four inches square extending through it longitudinally and centrally. Here *c* is the centre of the front end of the cylinder; and at two diagonal spaces from it will be the centre from which the boundary of the farther end is described. Circles running around the cylinder are described by the compasses from points on the axis. Observe that the length of the cylinder is not only measurable on the axis, but also on the other diagonal lines *3 4*, *5 6*, etc., which must all be equal—each being the measure of two diagonals.

Fig. 10 represents the outlines of a hollow cylinder four inches in length and ten inches in diameter, with walls one inch in thickness. As *c* is the centre of the front end, we first describe from it the outer circle, or periphery, of the cylinder, with a radius of five inches, and then the inner circle, with a radius of four inches, which leaves one inch between them for the thickness of the walls. From *d*, the centre of the farther end, we next describe two like circles, or parts of circles, the visible portion of the smaller circle being *1 2 3*, which is the visible portion of the farther inside boundary.

Fig. 11 is the same as Fig. 10 in outline, but fully shaded.

Fig. 12 represents a cylinder four inches in length and ten inches in diameter, with a solid cylinder, or axle, four inches in diameter and twenty inches in length, passing centrally through it—the axis of the longer cylinder coinciding with the axis of the shorter one. Here *c d* represents the axis of the short cylinder, and *a b* the axis of the long one. The length of either, or both, may be measured in any one of the several ways mentioned for measuring Fig. 9.

PROBLEMS FOR PRACTICE.

1. Draw a solid cylinder six inches in diameter and twelve inches in length.

2. Draw the same, but represent one quarter taken from it, similar to Fig. 4.

3. Draw the lower left-hand quarter of a cylinder whose entire dimensions would be eight inches in diameter and ten inches in length.

4. Draw the lower right-hand quarter of a cylinder of the same dimensions.

5. Draw the lower horizontal half of a cylinder whose entire dimensions would be eight inches in diameter and twelve inches in length.

6. Draw a hollow cylinder of fourteen inches in diameter, six inches in length, and one-inch thickness of walls.

7. Draw the *lower half* only of a hollow cylinder of twelve inches in diameter, 12 inches in length, and one-inch thickness of wall.

Blackboard Exercises.—The chalk crayon compasses will be required here. See page 49. Draw and shade all the figures on page 1, and also the problems.

PAGE TWO.—SCALE OF ONE FOOT TO A SPACE.

Fig. 13 represents the outlines of a solid, four feet by ten feet at the base, and eleven feet entire height: but the upper part is a semicircle. The front semicircular outline is described from the point *c*, and the farther one from the point *x*, distant, diagonally, from *c*, four feet. Observe that the side line, *a b*, is drawn so as to touch the semicircles at the extreme limit of our view of the semicircular top; and that the points *a* and *b* are necessarily at the intersections of diagonals, from *c* and *x*, with the semicircles. Let it be noticed that, as the measurements *1 2*, *3 4*, *5 6*, *7 8*, *9 10*, *a b*, and *c x*, are all equal in the real object, so they must be equal in the drawing.

Fig. 14 is the same as the preceding figure shaded.

Fig. 15 is similar to Fig. 14; but it rests on a base which projects laterally one foot; and the semicircular top also projects laterally one foot, equal to the projection of the base.

Fig. 16 is the same as the preceding figure fully shaded.

Fig. 17 represents the outlines of an archway, formed of two parallel walls, each two feet thick, six feet high, and six feet wide, placed eight feet apart, and surmounted by a semicircular arch of the same thickness as the walls on which it rests.

Fig. 18 is the same archway represented as reversed in position, and placed arch downward. This shows the outlines of the bases of the walls in full, and a part of the under side of the arch, which could not be shown in the drawing above it. Figs. 19 and 20 are the same as 17 and 18, shaded. In this way an object may be represented in different positions, when it is desirable to show as fully as possible the construction of its several parts.

Fig. 21 represents a semicircular arch resting on four pillars, two on a side. The pillars are four feet square and fourteen feet high, each pair resting on a base one foot in thickness, six feet wide, and ten feet in length, and surmounted by a cap (capital) of the same dimensions. The width of the archway, as measured from *a* to *b*, is twelve feet; and the height, from *c* to *z*, twenty-one feet. From the point *x* the front semicircles are described; and from *y* the semicircles which bound the farther end of the arch are described.

The divisions of the front of the arch, *2*, *3*, *4*, *5*, etc., are laid off by the compasses; and from the points of division straight lines are drawn toward the centre, *x*, just as the lines would tend if the real arch were laid with cut stone. Let it be observed, also, that the lines *5 7*, *6 8*, *9 10*, etc., drawn in the direction of diagonals, must all be of precisely the same length in the drawing, according to the scale, as they would be in the real arch. In fine, *all* diagonal, vertical, and horizontal lines in the drawing give, according to the scale, perfectly accurate measurements of the structure. Parts of perfect circles may then be measured or calculated with the same accuracy as in the real object.

PROBLEMS FOR PRACTICE.

1. Draw a figure similar to Fig. 14, but with a width of eight feet in front, depth of two feet, and total vertical height of ten feet.

2. Draw one like Fig. 19 in all respects, except that a central vertical section, two feet in depth, is represented as taken out, from right to left, throughout the entire archway—thus leaving the front and the rear of the archway perfect, and taking out the third part that lies between them.

3. Represent the same inverted—that is, by placing the arch downward.

4. Draw a figure similar to Fig. 21, but of the following dimensions: Place two columns on a side, each two feet square and twelve feet high, ten feet apart in front, and each pair six feet apart diagonally. Let each pair

have a base and cap similar to those in the figure, and also complete the arch in a manner similar to that in the figure.

Blackboard Exercises.—Figures 14, 19, and 20; also the foregoing problems.

PAGE THREE.—SCALE OF TWO INCHES TO A SPACE.

Fig. 22. We have here represented a pair of braces resting upon a platform two inches thick, eight inches wide, and twenty-eight inches long, and so placed as to be equally inclined toward a central line, *2 5*.

Fig. 23 represents a platform the same as in the preceding figure, but with *curvilinear* braces placed upon it, and equally inclined toward a central line, *2 5*. In this case, the bases of the braces, and the height *5 2*, being the same as in the preceding figure, we take any point, as *y* or *c*, from which we can describe, with the compasses, a curve that will pass through the points *1* and *2*. This point, *y* or *c*, may be farther from the left-hand brace, or nearer, according to the kind of curve that we desire for the brace: but, having taken it, we must describe, from the same point, the corresponding curve *7 9*. Diagonally from *y* or *c* we must take the point *z* or *x*, making *y z* or *c x* equal to *7 3*; and from *z* or *x* describe the curve *3 4*. This latter curve would terminate at the point *10*, the vertex of the farther face of the arch, on the under side. For describing the curves of the right-hand brace, we must take corresponding points at the left of the platform.

Fig. 24 shows the left-hand brace of the preceding figure, as drawn by itself alone. Here the point *10* is visible, and is seen to be in continuation of the curve *3 4*.

Fig. 25. This figure represents a semicircular arch eight inches (*g i*) in width, two inches' thickness of wall, described with an extreme radius (*c d* or *y g*) of twenty-two inches, and resting upon a base eight inches wide, two inches thick, and fifty-two inches in length—the whole divided vertically in the drawing, and at right angles to the face of the arch, so as to separate arch and platform into two equal halves, six inches apart. Suppose the two halves to be brought together centrally: the arch will then form a perfect semicircle.

Here all the curvilinear lines on the left are described from the points *c* and *x*, and those on the right from the points *y* and *z*. Let the pupil observe, that while the line from *10* to *b* is a curve struck by the compasses from the point *x*, that *b a* is a straight line, drawn according to the principles that were explained in relation to Figs. 13 and 14. When the curve from *10* to *b* has reached the point *b*, its continuation is below the visible surface of the arch; and the straight line *b a* is the surface of the arch, just as the line *b a* in Fig. 13 is the surface of the arch there represented.

Fig. 26 is the same as the preceding figure inverted. The upper sides of the platform and arch here become the under sides, and the points *x c* and *y z*, consequently, follow the inversion.

Fig. 27 represents a hollow cylinder of forty-eight inches' outside diameter, as measured from *1* to *2*; eight inches in length, as measured from *2* to *3*, *4* to *5*, *6* to *7*, or any where, diagonally, on the circumference; and walls of two inches' thickness. The two circles of the front end of the cylinder are described from the point *t*; and the visible parts of the two circles which bound the farther end of the cylinder are described from the point *x*, which must be two diagonal spaces from *t*, in order to make the length of the cylinder eight inches. The two front circles should be described first.

Fig. 28 is what is called a *quarterfoil* in architecture; which is an ornamental figure disposed in four segments of circles, the front face of which is a *conventional* resemblance of an expanded flower of four petals. (See Fig. 36, page 81.) The front segments of circles, forming the face of the ornament, are described from the points *a*, *b*, *c*, *d*, the four angles of a diagonal square; and as the ornament has a depth of eight inches, the segments of circles forming the farther side of the figure are described from the points *w*, *x*, *y*, *z*, two diagonal spaces from the other centres. The *shading* lines of the segments of circles are described from points between the front and rear centres, on the dotted lines. In drawing the figure, first describe the front segments from the points *a*, *b*, *c*, *d*, then from the other points describe such portions of the other segments as could be seen.

PROBLEMS FOR PRACTICE.

1. Draw a figure similar to Fig. 22, but make the plank base four inches longer, and place the braces four inches farther apart, while they shall be of the same height, *5 2*. Then on the lower side of the plank base place a like pair of braces, same distances apart, etc., and meeting at a point the same distance below the plank that *2* is above it.

2. Draw Fig. 23 with changes similar to those that were required to be made in Fig. 22 for the preceding problem, putting a pair of curvilinear braces *below* as well as *above* the platform.

3. Draw Figs. 25 and 26 united in one figure, and on the same base, but on opposite sides of it, and without any separation in the base or in the semicircular segments.

4. Draw a cylinder similar to Fig. 27, but with an extreme diameter of forty inches; walls four inches in thickness, and length of cylinder sixteen inches.

5. Draw a quarterfoil similar to Fig. 28; but take the centres of the front segments in the four corners of a diagonal square of only *four* diagonal spaces to a side: draw the outer segments with a radius of eight inches, and the inner with a radius of six inches; and make the quarterfoil only four inches in diagonal thickness. The *measure* for the radius must be taken on vertical or horizontal lines.

After drawing the foregoing problems, examine them carefully through the opening formed by the partially closed hand.

Blackboard Exercises.—Figs. 22, 23, 25; and any of the problems.

PAGE FOUR.—SCALE OF TWO INCHES TO A SPACE.

Fig. 29 represents a bracket of forty-four inches' height, thirty inches' projection, and eight inches' thickness. The front of the bracket (here the diagonal view) embraces two segments of circles; the upper one described with a radius, *3 a* or *3 b*, of twenty-two inches; and the lower one with a radius, *1 m* or *1 n*, of six inches. Observe that from the point *3* the curves *a b* and *f g* are described; and that from the point *4* the curve *c d* is described. The parts *c p* and *a n* are not portions of the curves, but are straight lines. From the point *1* the curve *m n* is described; and from the point *2* is described the hidden curve *o p*. In selecting the points *1 2* and *3 4* we are influenced wholly by the kind and extent of the curve which we wish to describe, just as in describing the curve of the real bracket; but the diagonal distance from *1* to *2* and from *3* to *4* is determined by the thickness of the bracket.

Fig. 30 is the same as Fig. 29, shaded in full.

Fig. 31 is a bracket of precisely the same dimensions as Fig. 30, but drawn in an inverted position, with the top of the bracket downward, by which means the hollows, or curved portions, are represented more fully than in the preceding figure.

Let the pupil observe that, wherever the thickness of the bracket is measured, it measures in all parts the same. Thus the diagonal lines *a c*, *d b*, *g h*, *p n*, *o m*, *s r*, etc., all measure the same.

Fig. 32 shows the outlines and mode of drawing a plain and regular *trefoil*, which is an architectural ornament disposed in three segments of circles, being a conventional representation of three-leafed clover—which is, botanically, a *trefoil* plant.

Observe that the points *1*, *2*, *3*, which are the centres from which the front curves are drawn, are at the three corners of an equilateral triangle; and that the points *4*, *5*, *6*, from which the visible portions of the curves of the farther side are drawn, are also at the corners of an equilateral triangle, one diagonal space distant from the front corners.

Fig. 33 shows the same trefoil as Fig. 32, but it is here cut into and through a cylindrical plank four inches in thickness, and thirty-six inches in diameter. Observe that *a* and *b* are the central points for describing the outlines of the cylinder.

Fig. 34. Here we have a quarterfoil of the same dimensions as in Fig. 28, but here placed within a cylinder of the same dimensions as that shown in Fig. 27. Observe that the central point of the front end of the cylinder is *t;* and that from this point, with a radius of eleven inches, we describe a circle which touches the convex front edges of the quarterfoil; from the same point *t*, but with a radius two inches greater, we describe another circle; and thus get the front face of the cylinder. In this manner the inclosing

cylinder should first be drawn; then the four central points, *a*, *b*, *c*, *d*, of the front face of the quarterfoil, should be designated at the four corners of a diagonal square. These points must be taken according to the size of the quarterfoil that can be drawn; but it will be observed that they are at equal distances, vertically and horizontally, from the central point *t*. The point *x* is taken the same as in Fig. 27; and the points *w*, *x*, *y*, *z*, the same as in Fig. 28. To get the full effect of this drawing, view it through the opening of the partially closed hand. (See page 50.)

PROBLEMS FOR PRACTICE.

1. Draw a bracket similar to Fig. 30, but of the following dimensions: height of bracket, forty inches; projection, 26 inches; thickness, four inches; the form of curves, etc., according to judgment.
2. Draw the same inverted, similar to Fig. 31.
3. Draw a trefoil on the basis of a triangle of thirty-two inches to a side; make it eight inches in diagonal depth or thickness; and let it have walls, which shall be two inches thick, similar to the walls of the quarterfoil in Fig. 28.

Blackboard Exercises.—The foregoing problems.

PAGE FIVE.—SCALE OF TWO INCHES TO A SPACE.

Fig. 35 is a conventional leaf pattern, drawn so as to represent four leaves whose central surface lines form the diagonals of a square; then these leaves are represented as being four inches in thickness, the under sides of the leaves being of the same form and dimensions as the upper sides.

First: the outline of *one side* of the upper or front surface of one of the leaves, say *A*, is drawn according to judgment. Then it will be easy, as shown in Book No. I., to draw the other side symmetrical with it by the aid of the ruled paper. Thus the curvilinear outlines of the leaf *A*, on both sides of the central line, are a little more than one space from the point *a*; nearly three spaces, on both sides, from the point *b*; four spaces from the point *c*; three spaces from the point *d*, etc. In this manner the outlines of the upper surfaces may all be accurately drawn by the hand alone.

Next: we have to draw the visible portions of the outlines of the under or farther sides of the leaves. If we take any point, as 3, in the leaf A, the point directly opposite to it, on the farther side of the leaf, must be just one diagonal space from it—that is, its opposite point must be seen at 4; the point opposite 5 must be seen at 6; the point opposite r, the end of the upper side of the leaf, must be at p, which latter point is the end of the lower side of the leaf. In this manner we may designate as many of the visible points of the lower edges of the leaf as we may desire; and then we have only to draw the curves through them to have the outlines of the under side of the leaf, so far as they can be seen from our point of view. In the leaf marked A, the extreme point of the under side of the leaf is seen at p, one diagonal space from r; in the leaf B, the extreme point of the under side of the leaf is seen at m, one diagonal space from s; in the leaf D, the extreme point of the lower side is seen at h, one diagonal space from g; and in the leaf C, the extreme point of the lower side of the leaf is at x, one diagonal space from o; and therefore it could not be seen unless the leaf were transparent. Thus the pupil will see what portions of the lower edges of these four leaves must be visible, and how he must draw them; and if he will remember that any point on the farther side of a vertical object put in cabinet perspective must be in a *diagonal* direction from its corresponding point on the nearer or front side, and will regulate the distance on the diagonal according to the scale adopted, he will find little difficulty in drawing any solid curvilinear object.

Fig. 36 is the same as Fig. 35, only shaded to show the form distinctly.

Fig. 37 is a solid isosceles* triangle, eight inches in thickness, as represented by the diagonal lines $1\ 2$, $7\ 8$, and $9\ 10$. Let it be understood that the face, $1\ 7\ 9$, of the triangle is in a vertical position, fronting the spectator. This face, then, presents to our view its natural proportions, and is measured in any direction by the measurement given to the vertical and horizontal lines of the ruling—two inches to a space.

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n *isosceles* triangle is one which has only two sides equal.

Taking the length, *a 7*, with the compasses, and applying it to the ruled lines, we find that *a 7* is a little more than twenty-eight inches long; and we find in the same manner that the base, *1 9*, is about seventeen inches long, as nearly as it can be measured by the compasses.* Let it be noticed here that the rule of *diagonal* measures does not apply to any lines whatever on the surface, *1 7 9;* because *1 7 9* is here supposed to be a *vertical* surface fronting the spectator, and not a *horizontal* surface. See Rule, page 85. Observe that the point on the under side of the triangle, opposite to *1*, is seen at *2;* the point opposite to *3* is seen at *4;* the point opposite to *5* is seen at *6;* the point opposite to 7 is seen at *8*, etc.—all in the direction of diagonals. The farther face of this solid triangle, being also in a vertical position, must measure the same as the front face.

Fig. 38 is the same in form and measurement as the preceding figure, but inverted in position. We here see the base, *1 2 10 9*, quite fully, but no portion of the sides.

Fig. 39 is a curvilinear quadrangular solid, supposed to be placed with the front side in a vertical position. It measures thirty-four inches between the opposite angles—as from *1* to *2* and from *3* to *4*, and is four inches in thickness. The curvilinear sides of the front surface are described with a radius of six diagonals, or about seventeen inches, from the four angles of an erect square; and the curvilinear sides of the farther face are described from the four angles of another erect square of the same size, whose corners are one diagonal space from the corners of the first-mentioned square. Observe that no part of the lower left-hand side or edge of the solid is visible; but the dotted line, *s t*, shows its position on the farther face of the solid.

Fig. 40 is the same curvilinear solid that is represented in the preceding figure, but the sides of the front face are here described from the four angles of a *diagonal* square. The

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* The exact lengths of the lines *a 7* and *1 9* can be found, inasmuch as each forms the hypothenuse of a right-angled triangle, which the ruling on the paper will show. In calculating their lengths, it will be found that *a 7* is a little more than twenty-eight inches long, and that *1 9* is a mere fraction less than seventeen inches.

[illegible] other sides are [illegible] from the [illegible]

[illegible] rectangular [illegible] inches in [illegible] inches.

[illegible] that the [illegible] from the point [illegible] and that the two [illegible] being visible [illegible] face from [illegible] The points [illegible] and [illegible] describing the curves of [illegible] are also [illegible] light wash of India [illegible] darker washes and the pencil.

EXERCISES FOR PRACTICE.

[illegible] frame *B C* and *D* at short distances apart, but in their [illegible] positions, and give to each a thickness of eight inches. [illegible] Fig. 36.

[illegible] of the same dimensions as described; but let the centre [illegible] in a horizontal position, twenty-eight inches in length— [illegible] point [illegible] being at the right hand.

[illegible] Fig. 38 of the same dimensions as Fig. 37, but having the centre [illegible] in a horizontal position, the point *b* being at the left hand.

[illegible] square frame of forty inches to a side, in the clear—that [illegible] of forty inches on the inside; let the depth be [illegible] and the thickness of the material one inch. Within this frame [illegible] similar to Fig. 40, having its curvilinear sides described from the [illegible] corners of the frame with a radius of twenty inches; and let the [illegible] eight inches in thickness. Shade the frame and the inclosed [illegible] properly.

[illegible] Fig. 41, as much of it as can be put on the board, and problem 1.

[illegible] SCALE OF TWO INCHES TO A SPACE.

[illegible] represents five quarter-sections of the rims of wheels, the front faces or edges of which are all *in the same* [illegible] fronting the spectator. If the rims were entire, they would represent what is called *a nest*, lying one within another. As the front edges all lie in the same plane, they are all described from the same centre, *a*, each rim being made two inches in thickness. The farther edges of the rim are likewise in one and the same plane; and as the rims are four inches wide, they must be described from a point, *b*, one diagonal space from *a*. The lines crossing the front edges of the rims all radiate from the point *a*.

Fig. 43 represents the side walls of a beveled tub, whose vertical height, when placed on its bottom, is sixteen inches; extreme diameter across the top, twenty-eight inches; and extreme diameter across the bottom, forty inches.

The top of the tub being supposed to be in a vertical plane fronting the spectator, and *c* being its central point, the outer circle of the top is described from *c*, with a radius, *c a*, of fourteen inches; while the inner circle is described with the radius, *c g*, of twelve inches.

Now, as the tub is to be sixteen inches in extreme height (or depth), we take the point *x*, four diagonal spaces from *c;* and the point *x* is then the central point of the bottom of the tub. Hence, with *x* as a centre, and with a radius, *x b*, of twenty inches, we describe a circle for the outer circumference of the bottom of the tub, thus making its diameter forty inches. With a radius two inches less, we describe from *x* the circle for the inner circumference of the bottom of the tub, which gives us the visible part, *d s f*, of this inner circumference of the bottom. The lines *r p* and *m n* are drawn tangent to (that is, *touching*) the outer circumference of the top of the tub, and the outer circumference of the bottom of the tub.

Suppose, now, that we wish to put circumference lines around the tub, and passing through certain points, *2*, *4*, and *6*, of the surface. In the same proportions that the line *i k* is divided by the points *2*, *4*, and *6*, divide the axis line *c x* by the points *1*, *3*, and *5;* then, with one point of the compasses in the point *1*, and the other extended to the point *2*, describe the first curve; with one point in *3*, and the other in *4*, describe the second curve; with one point in *5*, and the other in *6*, describe the third curve. The visib portion of the inside of the tub is viewed so obliquely th its widest portion, *t s*, is hardly one third of the apparent extent of *i k*; although both are, in reality, of the same extent. This figure should be viewed from above, and on the right, through the partly closed hand, when the effect will be very striking.

Fig. 44 represents nine cylinders, each fourteen inches in extreme diameter, four inches in depth, and walls one inch in thickness, placed in three rows forming a square, so that the cylinders touch one another.

Fig. 45 represents one of the stones from a carved moulding. It measures thirty-eight inches in height, twenty-six inches in breadth, and twenty-four inches in thickness as measured any where diagonally. In making a working drawing of such a figure, certain measurements can be given definitely for directions to the stone-cutter—as the height, the breadth, the distance from *b* to *11*, from *11* to *9*, from *9* to *d*; the size of the semicircle described from *c*, etc.; and all these measurements will appear accurately in the drawing. Then the curve, *3 5 7 d*, may be drawn so as best to please the eye. Having this drawn, the corresponding curve on the opposite side must be drawn, in all its parts, at a *diagonal* distance from the first curve representing twenty-four inches. Thus all the diagonal lines, such as *5 6*, *7 8*, etc., that can be drawn across the face of the carving, must measure precisely the same as the lines *c x*, *3 4*, *9 10*, *11 12*, etc.; for all alike measure the thickness of the stone.

Fig. 46 is a conventional heart-shaped solid, sometimes used in architectural ornamentation.

The points *a* and *b* being taken vertically above *c* and *d*, a suitable distance, according to judgment, the *face* of one half of the figure must be drawn by the guidance of the eye alone, but making the *width* of the face the same throughout, except where it varies slightly at or near the two extremities. It will then be easy to make the face of the other half symmetrical with it, according to directions given in Book No. II. Then, if the thickness of the ornament is to be four inches, or one diagonal, the diagonal width of the drawing is determined in the same manner as in the preceding figure.

PROBLEMS FOR PRACTICE.

1. Draw five quarter-sections of the rims of wheels, similar in all respects to those in Fig. 42, but placed in the upper right-hand quarter of the circle.

2. Draw the outlines of a bottomless tub similar to Fig. 43, but of the following dimensions. Extreme upper (front) diameter, twenty-four inches; vertical height, measured on the axis of the tub, twenty-four inches; extreme diameter of bottom of tub, thirty-four inches; thickness of walls, one inch.

Blackboard Exercises.—The foregoing problems.

PAGE SEVEN.—SCALE OF TWO INCHES TO A SPACE.

Fig. 47 represents a cubical block, twenty-eight inches square, having semicircular grooves of four inches' radius running diagonally through the centres of its upper, lower, and right and left hand sides, with a circular aperture of four inches' radius running from the front face diagonally through the centre of the block.

Observe that the centres *a*, *b*, *c*, *d*, *e*, *f*, from which the semicircles on the front and on the farther side are described, are situated at the middle point of the edges of the cube, just where they would be placed for marking out the semicircular grooves on the real cube.

Figs. 48 may be supposed to be cut out of a block twenty-eight inches in height (*m n* or *e g*); twenty-eight inches in depth (*m o* or *e f*); and thirty-two inches in width (*m e* or *n g*). The figure consists of a frame-work having four corner posts of two by four inches, supporting a half-cylinder above and one below, with their concave surfaces outward, the whole cut out of the block. The thickness of the walls of the half-cylinders is four inches. Their semicircular ends are described from the points *a*, *b*, *c*, and *d*. The point *d*, for describing the farther end of the lower half-cylinder, must evidently be at the middle of the farther lower edge of the block, just as *c* is at the middle of the front lower edge. But *c* is eight spaces, horizontally, to the left of the corner *g*; so must *d* be eight spaces, horizontally, to the left of the corner *h*. If the pupil will carry out all the measurements, just as they are in the real object, he will find

should first be traced lightly, and only filled in firmly when the positions of all the parts are distinctly seen.

PROBLEMS FOR PRACTICE.

1. Draw a block the same in size as Fig. 47, but with semicircular grooves of eight inches' radius taken out centrally and diagonally through four of the sides, as in Fig. 47.

2. Draw a figure similar to Fig. 48; but let the height of the front be twenty-eight inches, its width twenty-four inches, and the diagonal depth of the block twenty inches; let the greater curves of the semicircular grooves be struck with a radius of ten inches, and the lesser curves with a radius of eight inches.

3. Draw a solid cylinder of six inches' radius, and twenty-four inches' diagonal length, and let it rest centrally upon a diagonal platform twelve inches wide in front, four inches thick, and twenty-four inches' diagonal length, so that the ends of the cylinder shall be even with the ends of the platform.

Blackboard Exercises.—Figs. 48 and 50, and problems 1 and 3.

PAGE EIGHT.—SCALE OF THREE INCHES TO A SPACE.

Fig. 54 represents a wheel eleven feet and a half in extreme diameter; rim, thirty inches wide and six inches thick; the cylindrical nave or hub, four feet in diameter and thirty inches in length; and having eight flat spokes or radii, each six inches thick, and the same width as the rim and hub.

The foregoing dimensions being given, we proceed in the following manner to make a drawing of the wheel.

1st. Taking x as the centre of the vertical front face of the wheel, with a radius, $x\ a$, of five feet nine inches, describe the circle $a\ b\ c\ d$ for the circumference of the wheel, being eleven feet and a half in diameter.

2d. Six inches within the circumference, with the radius $x\ e$, describe a circle, which, with the former, will give the thickness of the rim—six inches.

3d. With the radius $x\ f$, of two feet, describe a circle for the circumference of the hub, four feet; and with the radius $x\ g$, of one foot, describe a circle for the cylindrical opening which is to receive the axle, which is to be two feet in diameter.

4th. Trace lightly the vertical, horizontal, and diagonal

Observe with what accuracy all the parts, in accordance with the scale laid down, and with the principles of representation adopted, maintain their correct measurements, the same as in the real object. Thus all measurements at right angles across the outside or the inside of the rim of the *real* wheel, and across the outside or the inside of the hub, measure the same, thirty inches. So, also, in the drawing, all the *diagonal* lines across the rim or the hub—as *1 2*, *3 4*, *5 6*, *7 8*, *v w*, etc.—measure precisely the same, five diagonal spaces, or thirty inches.

Let this wheel be viewed as directed on page 50. The pupil should not only draw this wheel, but also one of a different size, and with the spokes arranged differently.

PROBLEM FOR PRACTICE.

1. Draw a wheel, similar to Fig. 54, of the following dimensions: Extreme diameter, ten feet and a half; rim, thirty-six inches wide and three inches thick; the cylindrical nave, or hub, thirty-six inches in diameter, three inches in thickness, and thirty-six inches in length; and having eight flat spokes or radii, each three inches thick, and the same width as the rim and hub.

Blackboard Exercise.—Let the pupil plan and draw a wheel similar to that described in the problem, and of such size as the board will permit.

PAGE NINE.—SCALE OF THREE INCHES TO A SPACE.

Fig. 55 represents a wheel eleven feet and a half in extreme diameter; extreme width of double rim and double hub, four feet; thickness of rim, three inches; extreme diameter of the hub, four feet, and diagonal extent of the two parts, four feet; thickness of rim of the hub, three inches; thickness of the broad paddle-like spokes, three inches, and width four feet.

This figure consists of two similar wheels, the second being placed immediately back of the first, and each having its separate rim and hub, but the two being united in one wheel by the broad paddle-like spokes, which are common to both.

1st. In drawing this figure, draw the front wheel first, in the same manner that Fig. 54 was drawn—*w* being the centre of the front face of the wheel, and *x* the centre of the opposite side. Draw the circles lightly with the compasses; then draw lightly, in like manner, the front and rear circles of the farther wheel, from their centres *y* and *z*.

2d. Observe that the eight broad spokes are arranged in a manner different from those in Fig. 54, there being no spokes on the diagonal lines *3 12* and *7 a;* and we have placed none on these lines, because, in these positions, there could be no side view of the spokes that are in the direction of *3 12*, as there is none in Fig. 54. This is, therefore, a better arrangement of these portions of the wheel.

3d. In order to arrange the eight spokes equidistant from one another, and intermediate between the centrally vertical, horizontal, and diagonal lines of the wheel, first draw these lines lightly, and mark their points, as *1, 3, 5, 7, 9, 11*, etc., on the circumference of the front face of the wheel; then take the points *2, 4, 6, 8, 10*, etc., intermediate between them, and connect the opposite points by light lines passing through the centre, *w*. On each side of these latter lines lay off half a space (an inch and a half), and draw lightly the lines which determine the front width of the spokes. Each pair of these lines passes equidistant on both sides of the centre, *w*. The extreme ends of the spokes are then all drawn *diagonally* across both parts of the rim, and the other ends of the spokes are drawn in like manner across both parts of the hub. The dotted continuations of the lines show where the lines would appear if the parts which obstruct the view were transparent.

Observe how the broad spokes are let in, centrally, between the two rims which compose the hub, and that they are let in the exact depth of the rims, three inches. The portions that are let in are, therefore, continuous with the inner sides of the rims of the hub. Every part of this wheel will show beautifully when viewed as directed on page 50.

If the pupil will be careful to have all the measures correspond with the measures of the real wheel of the given dimensions, and will connect those points, and those only, that are connected in the real wheel, he will have no difficulty in drawing this, and all similar representations of real objects, with mathematical accuracy.

PAGE TEN.—SCALE OF THREE INCHES TO A SPACE.

Fig. 56 is a drawing of what is called a *crown-wheel*, which is a wheel with cogs or teeth cut out of the rim, and set at right angles to the plane of the wheel. See a different representation of this same wheel in Fig. 23 of Book No. IV.

In this figure the ends of the projecting cogs or teeth, thirty-two in number, form the vertical front face of the wheel, which has *w* for its centre; and the extreme diameter of the wheel—*1 5* or *3 7*—is eleven feet. The rim, including the teeth, is thirty inches wide and three inches in thickness, and the cogs are one foot in length; the four supporting arms (or spokes) of the wheel, which are six by twelve inches, are set back even with the farther face or side of the wheel, and are back eighteen inches from the ends of the cogs: *x* is the centre of the farther vertical side, and hence *w x*, the proper axis, is thirty inches in length; but *v x*, the axis of the short hub, is only twelve inches in length. The hub is eighteen inches in diameter, as measured from *m* to *n*, and its rim is three inches in thickness. Through the hub passes an axle on which the wheel turns, twelve inches in diameter and sixty inches in length, having *s t* for its axis.

1st. In drawing a figure with the dimensions given for this wheel, first take some point, as *w*, for the centre of the front face, and with a radius, *w 3*, of five and a half feet, describe the outer front circumference of the circle of cogs; and then, with a radius three inches less, describe the inner front circle, which gives the thickness, three inches, of the cogs. From *x* describe two like circles for the farther edge of the rim.

2d. Divide the front circumference into eight equal parts, by the dotted vertical, horizontal, and diagonal lines, radiating from the centre, *w;* then, with the compasses, make eight equal divisions in each of these parts, which will give to each part four equal cogs, with spaces between them of the same width as the cogs.

3d. As the cogs are to be twelve inches in length, take the point *y*, twelve inches diagonally from *w*, and with the [illegible] ne [illegible] will [illegible] in the [illegible]

[illegible] the cogs [illegible] outward [illegible] the follow- [illegible] the ends of the cogs that limit [illegible] backward must [illegible] be directed toward [illegible] and the corresponding [illegible] of the rear of the cogs must be directed toward their common centre, *q*—as *b q*, *d q*, *f q*, *p q*, etc.—[illegible] the rear wheel.

[illegible] The lines that bound the teeth *lengthwise*—as *h i*, *j k*, [illegible] must be drawn in the direction of diagonals. These [illegible] drawn next after the *end* lines that limit the width of the cogs, and, when drawn, they fix the position of the [illegible] lines of the cogs.

6th. From the point *o*, the centre of the front face of the short hub, describe the two circles, one with a radius of nine inches, and the other with a radius of six inches, for the front face of the hub, and from *r*, with a radius of nine inches, describe a circle (only a small part of which is seen) for the outer circumference of the farther face of the hub. From *s* and *t* are described the circles for the ends of the axle.

7th. As *o* is the centre of the vertical circle which limits the front ends of the spokes, from *o*, with a radius of five feet and three inches, describe a circle for that purpose. The *central* lines of the front faces of the spokes must then pass through *o*, and the width of the spokes is laid out at equal distances on each side of these central lines. The shading is similar to that of the preceding two figures.

The dimensions of the wheel are well seen in the dotted squares *A B C D*, *E F G H*, which bound its front and rear vertical faces.

PAGE ELEVEN. SCALE OF THREE INCHES TO A SPACE.

Fig. 57 represents the face or side of a *ratchet* wheel, a wheel which has teeth like those of a circular saw. The teeth may be either long and sharp-pointed, or short and more blunt in appearance; but in either case the inner edges of the teeth are not directed toward the centre of the wheel.

1st. This figure represents the face or side of a wheel fifty-four inches in extreme diameter, having *x* for its centre. After describing the outer circumference, take any required distance on a diameter, as *3 d*, and from *x*, with the radius *x d*, describe the circle *d e f*, which is to limit the length of the teeth.

2d. Divide each quarter of the circumference into as many equal spaces as there are to be teeth in it. From the centre, *x*, describe an inner circle, *a b c*, large or small, according to the amount of *bevel* that is to be given to the teeth.

3d. From the points of division in the circumference, as *2*, *3*, *4*, etc., draw lines *tangent* to (touching) the inner circle, as seen in the drawing—such as *3 a*, *8 c*, etc.; and also, from the same points of division in the circumference, draw the tooth lines *3 g*, *h o*, etc., intersecting the former tangential lines on the second circle. But the drawing itself will explain every thing that is needed to be understood.

Fig. 58 represents not only the side view of a ratchet wheel, but the dimensions, also, of all its parts, in length, breadth, and thickness.

Fig. 58 represents a ratchet wheel twelve feet in extreme diameter, having a rim fifteen inches wide and six inches thick, into which thirty-two teeth are cut, to a depth of nine inches. It has a hub forty-two inches in diameter, with a central cylindrical opening for a shaft, or axle, twelve inches in diameter: and twelve spokes, of three by six inches, and thirty-six inches long, set at equal distances apart, connect the rim and the hub.

1st. Here *x* is the centre of the vertical front face or side of the wheel, and *y* the centre of the farther side. As the circle *1 1 1 1*, described from *x*, with a radius of six feet, limits the points of the teeth on their front face, so the circle *2 2 2 2*, described from *y*, with the same radius, limits the points of the teeth on the farther side of the wheel. Therefore, if we divide the outer circumference, *1 1 1 1*, into thirty-

[illegible]

[illegible] X X, twelve inches [illegible] diameter and [illegible] in length; four inches [illegible] ends of which are two drums, W W, each [illegible] inches in diameter and twelve inches in thickness. Projecting from the centre of the circumference of each drum, at right angles to the axis, are eight spokes or levers, three inches by four inches in size, and with a projection of ten inches beyond the drum.

A smaller shaft, or axle, *Y Y*, six inches in diameter, projects, centrally, sixteen inches beyond the ends of the larger shaft, and, immediately beyond the ends of this larger shaft, rests in two bracing supports, each eight inches wide, fitted to receive the axle.

At *A* the front drum is drawn separately, together with the end of the shaft and the projecting axle, but without the spokes or levers, and without the support in which the axle rests. Here *a* is the centre of the axle, where it connects with the shaft, and also the centre of the end of the shaft, while *b* is the centre of the front face of the drum, and *c* the centre of the farther face or side.

At *B* is a separate drawing of the support in which the front axle rests. The timber forming the base in which the braces rest is forty inches in length, four inches in vertical thickness, and eight inches in width. The supporting braces are two by eight inches, and about twenty-three inches in length *above* the base. The *tie-brace* at the top is cut out in a semicircular form, six inches in diameter, to receive the axle.

At *C* is a representation of the drum, *W*, with the spokes in their places. It is here drawn separately for the purpose of showing the method of placing the spokes accurately in the centre of the cylindrical surface of the drum. This drawing may be made in the following order:

1st. Take some point, *a*, as the centre, from which, with a radius of fourteen inches, describe the circumference of the nearer and visible end of the drum; and from *d*, twelve inches diagonally from *a*, on the axis, with the same radius, describe the farther circumference, only half of which is visible.

2d. Now, as the spokes to be inserted are three inches wide on their face or front side, and four inches diagonally, they must be inserted in the central *third* portion of the cylindrical surface of the drum. We therefore take *a d*,

[illegible]

[illegible]

[illegible]

through the points *5*, *3*, *1*, *8*, *w*, *y*, etc., thus limiting the diagonal width of the spokes. Suppose, now, that the corner face lines of the spokes, as *g e*, *16 r*, etc., extend to the nearer face circle *e 8 x*. From the intersections of these corner lines with this nearer face circle, giving the points *t*, *r*, *v*, *z*, *x*, etc., we draw lines diagonally, as *t u*, *r s*, *e l*, *v w*, *x y*, etc., which give us the side boundary-lines of the ends of the spokes.

6th. The lines *16 17*, *11 18*, *12 19*, etc., showing the intersections of the sides of the spokes with the surface of the drum, we also draw diagonally—for *all lines that are parallel in the real wheel must be parallel in the drawing.*

The outlines of the spokes are thus completed—all accurately drawn in their proper places, as projecting from the central third part of the surface of the drum.

At *D* the several parts described in the sections *A*, *B*, and *C* are put together, resting on a timber platform. Let the pupil verify the following measures according to the scale.

1st. The distance, *x y*, between the drums, is fifty-six inches. The distance, *c d*, *on the axis*, between the centres of the inner faces of the two drums, must give the same measure.

2d. As each drum is twelve inches in thickness, the distance, *r z*, between the outer faces of the drums, must be eighty inches. The distance, *b g*, between the points on the axis, from which the circumference of these outer faces are described, must give the same measure.

3d. As the large shaft extends four inches beyond the extreme faces of the two drums, the length of the shaft, whether measured diagonally on its surface or on its axis, must be eighty-eight inches. The farther end of the large shaft is concealed from view, but its position can be easily determined by counting twenty-two spaces diagonally from the point *5*.

4th. As the tops of the bracing supports of the axle are in immediate contact with the ends of the shaft, the distance *between* the inner faces of the tops of these supports must also measure eighty-eight inches.

5th. As each of the bracing supports is eight inches in ith the distance *s t*, between the extreme faces of the ns of these supports, must be one hundred and four inches. thus get the point *t*, and the outlines of the corresponding n of the farther brace.

h. As we have the point *i* at the bottom of the nearer ace, we now know that the corresponding point *z* of the ther brace must be one hundred and four inches from it agonally—that is, twenty-six diagonal spaces. The distance from *z* to *i* must measure the same.

have been thus particular in describing the drawing this figure for the purpose of showing that every part ay be drawn with the most perfect accuracy, and so as to ow its exact measurement. With the aid of the ruled rawing-paper all such drawings may be executed with reat rapidity; and any required degree of modification, ies, from the plain angular forms, may be given to them. hus the spokes may be round, or even tapering, and lighter than here shown, and all the parts may be modified, hile at the same time accuracy of representation may be dhered to provided the very plain *principles* of this mode f representation are clearly understood.

DRAWING-BOOK No. IV.

CABINET PERSPECTIVE—MISCELLANEOUS APPLICATIONS.

I. DIFFERENT DIAGONAL VIEWS OF OBJECTS.

In the preceding two books on Cabinet Perspective, objects have been represented not only as viewed *diagonally*, with their principal surfaces in vertical and horizontal positions, but as viewed diagonally from one particular point, which point is supposed to be diagonally at the right of the object, and above it. But although, for the purpose of avoiding confusion, it is best to represent all objects from this one point of view whenever it can be done to advantage, yet objects may be represented diagonally in cabinet perspective equally well from any one of *four* points of view, as will be seen from the drawing on the first page of Book No. IV.

PAGE ONE.

1st. *Upper right-hand view.*—In division *A* the objects are represented as viewed diagonally from *above*, and at *the right*, the same as in all the drawings in the preceding two books. The arrow, *m*, is represented as coming from the position, at an infinite distance away, from which the objects in *A* are viewed.

2d. *Lower right-hand view.*—In division *B* the objects are represented as viewed from *below*, and at *the right;* and here the arrow, *n*, is represented as coming from the position, at an infinite distance away, from which the objects are viewed. It will be observed that the bracket, f, is best represented in its true position from the point of view here taken.

3d. *Lower left-hand view.*—In division *C* the objects are represented as viewed from *below*, and at *the left;* and here the arrow, *o*, is represented as coming from the point from which the objects are viewed.

4th. *Upper left-hand view.*—In division *D* the objects are represented as viewed from *above*, and at the *the left;* the arrow, *p*, being represented as coming from the position, at an infinite distance away, from which the view is taken.

Thus two of the views are represented as taken from *above*, one from the right and the other from the left; and the other two views are represented as taken from *below*, in like manner. In this way we get inside views of the curves of the four brackets; but all of the brackets might have been drawn equally well according to the plan of division *A*, if they had been placed in proper positions for the purpose. In *A* the bracket, *e*, is inverted, for the purpose of showing to the best advantage the inside curves; and the brackets *f*, *g*, and *h* might have been drawn in similar positions.

II. GROUND-PLANS AND CABINET-PLANS OF BUILDINGS.

PAGE TWO.—SCALE OF ONE FOOT TO A SPACE.

Fig. 1 is the ground-plan of a building, whose outer walls, one foot in thickness, embrace an extent of eighteen by twenty-six feet. It will be seen that the lined paper is admirably adapted to ground-plans or surface representations, as it is only necessary to adopt any convenient scale, when the plan may be laid down with perfect accuracy without any measurement, by simply counting the spaces. In a ground-plan, like Fig. 1, we can show the position and thickness of the walls and partitions, and the width and position of doors and windows, etc.

Fig. 2 is a cabinet-plan of the walls, doors, windows, etc., Fig. 1; the whole being represented from the foundations upward to the extent of three feet. Observe that all the measures in Fig. 2 are the same, according to the scale adopted, and the principles laid down for cabinet drawing, as in Fig. 1. Thus, in Fig. 2, the length of the side wall, *1 2*, is twenty-six feet; and the distance, *1 4*, is eighteen feet—the same, in both cases, as in Fig. 1. But in Fig. 2 it is shown that the windows in the front room come down within six inches of the bottom of the wall, while those in the back room come down to within two feet and a half of the bottom of the wall. These are features which can not be shown in a ground-plan.

Fig. 3 is another ground-plan, representing a building with two rooms, one fourteen by sixteen feet, and the other thirteen by sixteen. The position for a stair-way is given in a corner of the large room, and the position for a shelf is given in the other. Rectangular openings for fire-places are also given in the partition wall; but we can not show any thing more than a mere *ground*-plan in this kind of drawing, and must look to the next figure for any thing like details.

Fig. 4 is a cabinet view of the plan of Fig. 3, embracing not only the ground-plan, but the walls, bench, stair-way, platform to entrance, etc.—*all*, in fine, that belongs to the plan of the building, to the extent of three feet above the stone foundations, while the height of the stone wall above the earth is shown also.

In making a drawing of this kind it is best to begin at *the top*, and work downward, tracing every thing lightly at first. The walls may be made of any desired height; and the only objection to making them their *full* height is that the front wall will then obscure the rear wall. It is well, sometimes, to draw the front wall and the right-hand wall only two or three feet high, and represent the other two of their full height, with beams, joists, etc., projecting a short distance from them. Or any section of the building may be represented separately, and a scale larger than that used for the walls may be adopted for portions that require a minute representation. In this manner the most elaborate building may be fully represented, even to the most minute details, and with far greater accuracy than could be attained by description alone.

Fig. 5. At *A* are represented a stair-way and platform, with the side to the front; and at *B* the same are represented with the stairs presenting the front view. Observe that the measurements in the one case are the same as in the other—the distance *5 2* being the same as *6 4*, and *1 8* the same as *3 7*, etc.

PROBLEM FOR PRACTICE.

(This may be omitted by the younger pupils.)

It is required to draw, in cabinet perspective, a building similar to the ground-plan of Fig. 3, but of the following dimensions: Length of building (*1 2*), forty feet; width (*1 3*), twenty-four feet; thickness of walls, eighteen inches; room on the left, twenty by twenty-two feet in the clear; room on the right, seventeen by twenty-two feet in the clear. Draw the front wall, division wall, and wall on the right-hand side, only three feet high, but the wall on the rear, and left-hand side, eleven feet high. Put in the openings for the windows, *a* and *b*, in the centres of the ends of the rooms, three feet from the floor, four feet wide, and seven feet high; the door, *c*, two feet from the partition wall, four feet wide, and seven feet high; let a beam one foot square at the end rest upon the rear wall and left-hand side wall; let a beam of the same size project from the rear beam four feet over the partition wall; and let one project forward from the upper corner above *2*, four feet; and let one extend from the corner above *3*, four feet to the right, over the front wall. Carry a tier of four shelves, two and a half feet apart, twelve feet long, and two feet wide, across the window, up against the rear wall and right-hand corner of the room on the right, the top of the lower shelf being two and a half feet from the floor. Carry a flight of eight stairs, four feet wide, with one-foot risers and one-foot tread, up against the rear wall of the room on the left, onto a platform four feet square in the corner; and then have four stairs running from the platform toward the front, up to the top of the wall. Let there be one supporting post, six inches square, at the angle where the stairs turn, and one to support the end of the last stair, three feet six inches from the wall, and coming out flush with the end of the stair.

Let the other windows, doors, etc., be similar, in size and position, to those in Fig. 1.

PAGE THREE. SCALE OF ONE FOOT TO A SPACE.

Fig. 6 is the ground-plan of a building twelve feet in extreme width, and thirty-four feet in length, with a platform entrance to the front of two by six feet, and three steps, each a foot wide, ascending to it. There are two rooms, each ten by twelve feet, with a hall between of six by ten feet, and openings four feet wide in the partition walls, for sliding-doors, leading from the hall into the two rooms. The jambs of the fire-places bevel outward. At *A* the ground-plan of the fire-places is drawn on a larger scale, showing the exact bevel of the jambs.

Fig. 7 is the same as the preceding figure, here changed to the cabinet-plan, and drawn to the same scale as Fig. 6. The ground-plan of the walls represented in Fig. 6 is, in Fig. 7, transferred to a stone foundation, which is raised one foot above the ground at the corner *1*, and two feet at the corners *2* and *3*. Hence the front steps, which have six-inch risers and one-foot tread, must rise a distance of two feet.

At *B* is a cabinet view of the fire-place, drawn to the same scale as the ground-plan in *A*. Observe how the figures of the one correspond to the figures of the other in relative position, and that the measures are the same in both.

Fig. 8 represents a series of platform structures of different elevations. Thus, if we begin with the level at *J*, we ascend toward the left an inclined or sloping plane until we rise three feet, to the level of *H*. Rising six inches from *H*, we step onto the platform *G* or *K;* four steps, each of six inches' rise, then bring us onto the platform *I* or *F;* eight steps, each of six inches' rise, then bring us to the level of the platform *D*.

Now it would be difficult to ascertain whether *E* is higher than *D* or not, if we did not know, or *find out*, the height of the box-like frame-work on which the flooring, *E*, rests, and likewise its projection beyond the sides of the frame. The size of this frame-work is sixteen feet square; and the floor, here represented as six inches in thickness, projects one foot on all sides, except toward *D*, where there is no projection. The frame-work (without the floor) rises four feet above the corners *5* and 7, and six feet above the corner *6*. Hence the upper corners of the frame-work would be seen at the points *1* and *2*, the former four feet vertically above *5*, and the latter six feet vertically above *6;* and the other corners at the points *3* and *4*, at the intersections of the

At *C* are the outline walls of a building, the outer walls being two feet in thickness. At *L* is seen the opening into a pit, extending downward below the flooring.

Observe that the window openings in the frame of *E* are the same in relative position, number, size, etc., on the right-hand side as on the front, and that there is the same *real* width of window-sill represented on the right-hand side as on the front.

To master the drawing of the platforms in Fig. 8—with the projection of *E* on three sides, and no projection toward *D*—with the arrangement of the posts, etc., the whole should be drawn on a larger scale.

PROBLEM FOR PRACTICE.

Draw a figure similar to Fig. 8, but with the following measures: Let the *frame* on which the flooring of *E* rests be twenty-seven feet square. Height of frame from corners *5* and *7* six feet, and from corner *6* eight feet. On this frame place a floor one foot in thickness, and one foot projection on all sides except toward *D*, where there is to be no projection. Posts of platform *E* four feet high above floor, six by twelve inches in size, and arranged as in Fig. 8. Platforms *I* and *F* six feet wide. Platform *D*, and steps ascending to it, eight feet wide; and a sufficient number of steps, each six inches' rise and twelve inches' tread, for *D* to be six inches below *E*. Top of railing of *D* to be even with top of railing of *E*. Let there be four window openings, or recesses, in front, and the same number on side of *E*, each three feet wide and four feet high, a foot and a half from the top of the *frame;* and let the depth of the recesses be one foot. These window openings to have three feet space between them, and those nearest the corners to be three feet from corners. In other respects make the structure similar to Fig. 8, omitting *C*.

III. CYLINDRICAL OBJECTS IN VERTICAL POSITIONS.

The representations of circles, wheels, cylinders, etc., in cabinet perspective, have thus far been made on the supposition that the *axes* of the cylinders, etc., lie in a horizontal position, although placed diagonally with reference to the point from which the view is taken; and the vertical cylindrical ends have been drawn perfect circles, as though they were directly in front of the spectator. This is the case with all the cylindrical objects represented in Book No. III. Thus, referring to the cabinet cube for illustration, we have hitherto represented the circle as drawn on the front vertical face of the cube. But if the circle were to be drawn on the obliquely viewed *top* or *side* of the cube, the circle would have the form of a particular kind of *ellipse*,* as the following illustration will show.

I. ELLIPSES ON DIAGONAL BASES.

PAGE FOUR.—SCALE OF TWO INCHES TO A SPACE.

[N. B.—The description of Fig. 9 should be read over, but the figure need not be drawn.]

Fig. 9. We have here drawn a cabinet cube of twenty spaces (forty inches) to the side, the nearer vertical face of the cube fronting the spectator; and on this front face of the cube we have described a circle touching the centres of the four sides of the square. As this circle is drawn with a radius of ten spaces, the circumference will pass through the intersections of the ruled lines of the paper marked *2*, *4*, *8*, *10*, *14*, *16*, and *20*, *22*, in addition to the points *0*, *6*, *12*, and *18*, making twelve points in the intersections of the ruled lines through which it will pass.† On the top, and also on the right-hand side of the cube, we have also *represented* a circle of the same size as that in front—the circumference in each case touching the centres of the four sides of the diagonal square within which it is drawn, and also passing through the corresponding points *2*, *4*, *8*, *10*, *14*, *16*, and *20*, *22*. The representations on the top and right-hand side of the cube are *ellipses;* and a sufficient number of points in their curves may be known to enable one to draw the curves with great accuracy.

Thus, take the construction of the upper ellipse for illustration: First, rule the upper surface of the cube to correspond to the ruling on the front face. Then all the lines, and their intersections, on the upper surface, will correspond to those on the front face. Mark any required number of points on the front face, through which the circle passes, and mark the corresponding points on the upper surface, and then through these latter points draw the ellipse, and it will correspond to the circle. Thus, if the ellipses be accurately drawn, they will pass through the points *2*, *4*, *8*, *10*, *14*, *16*, *20*, *22*, etc., of the top and right-hand side of the cube. More points may be taken, if required, and thus the ellipses may be drawn quite accurately by hand. This mode must give an accurate cabinet representation of a circle drawn on the top and side of a cube. View the whole figure through the opening of the partly closed hand for a half-minute or so, and the ellipses will gradually appear as perfect circles.

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* An *ellipse* is an oval or oblong figure, which corresponds to an oblique view of a circle.

† A circle drawn with a radius of 5, 10, 15, 20, 25, or 30 spaces, etc., will pass through twelve points in the intersections of the ruled lines. This is susceptible of geometrical proof.

But the two *side* curves of each of these ellipses may be quite accurately drawn in the following easy manner. Suppose we wish to draw the ellipse in the cabinet square *B C F E*. Place one point of the compasses in the point *B*, and extend the other to the point *a*, the centre of the opposite *long* side; and with the compasses thus extended strike a curve across *B F*, the diagonal of the square, and dot the point *b*. Then, with one point of the compasses in *F*, and with the same stretch, dot the point *d*, corresponding to *b*. With the compasses still spread as before, first with the point at *x*, and afterward at *a*, strike the curves intersecting on the right at *m*. Then, with one point of the compasses in *m*, strike the side curve *a x* of the ellipse. It may be prolonged in the direction of *a* to *7*. Then, with the points of the compasses respectively in *18* and *12*, the centres of the other two sides, with the same stretch as before, strike the curves that intersect at *n*; and from *n* as a centre describe the other side curve *12 18*, prolonging the curve to about the point *19*. Half the distance from *d* to *B* will give the point *21* of the ellipse, on the diagonal; and half the distance from *b* to *F* will give the corresponding point *9*. The diagonal distance from *9* to *21* is also [illegible] same distance as [illegible] intersecting curves [illegible] approximately [illegible]

[illegible] drawn by the eye [illegible] curves on the diagonals [illegible] referred to as a guide [illegible] similar end curves in ellipses [illegible] seldom be necessary, and not [illegible] ellipses in those positions. [illegible] most convenient to draw the [illegible] positions and in the manner shown in [illegible]

[illegible] RECTANGULAR BASES.

[illegible] Suppose [illegible] left-hand [illegible] that the [illegible] should [illegible] front face [illegible] same width [illegible] Fig. [illegible] vertical cylinder, may be drawn after the manner first indicated in Fig. 9, by dotting points to correspond, in relative position, to the points marked on the circle below. The ellipse is here drawn in this manner, by dotting the points, and then drawing the curve through them by hand. All the points in the ellipse that are accurately marked in this way must be correct. As the circle, described with a radius of ten spaces, passes through the twelve points *0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22*, so must the ellipse above it, if accurately drawn, pass through the corresponding twelve points, numbered in like manner.

Side Curves.—But the *side* curves, at least, of this and of all similar ellipses, may be very accurately drawn by the compasses in the following manner. Place one point of the compasses in *A*, and extend the other to *6*, the middle of right-hand side of the cabinet square *A B C D* (or place in *B* and extend to *18*); then, still continuing the point in *A*, with the other point strike the central vertical line, *12 0* prolonged, in *w*. Then, with one point of the compasses in *w*, and the other extended to *12* above, describe the curve *9 12 15*. Then, with one point in *C*, and the other extended to *18* (half way between *A* and *D*), strike the line *0 12* prolonged above *12*, for the point on the opposite side to correspond to the point *w*; from which point, thus found, and with the other point of the compasses extended to *0*, describe the curve *3 0 21*. The two side curves will thus be drawn very accurately.

End Curves.—The end curves may be best drawn by hand, in the following manner, by the aid of guide circles. Thus:

On the line *6 18* take any point, *v*, so that *v 6* shall be equal to *v 9*, and from *v* describe a circle passing through the points *9, 6, 3*: this circle will then serve as a guide for drawing the end curve of the ellipse, which must pass a little within the circle, and at the same time be a natural and graceful continuation of the side curves. The other end curve is drawn in a similar manner.

Note.—The representation given in Fig. 10 may be called *upper vertical* rectangular perspective. But if the spectator were horizontally to the *right* of the centre of the front circle, at the proper distance, he would not see the top of the cube, but the right-hand side would be visible; and on that side might be described an ellipse like the one now seen at the top of Fig. 10; only the longest diameter of the ellipse would then be in a vertical position. This might be called *right horizontal* rectangular perspective. In the same manner, if the spectator were horizontally to the *left* of the centre of the front circle, the left side of the cube might be seen, and on that side might be described an ellipse, and this might be called *left horizontal* rectangular perspective. In the same way the spectator might be supposed to be vertically *below* the centre of the front circle, so as to see the lower side of the cube, on which might be described an ellipse. But this latter would be a position so unusual that we would not recommend objects to be thus drawn. The ellipse is drawn in *precisely the same manner* in the several positions here mentioned.

The position of the horizontal cylinder in Fig. 13 is different, as regards the spectator, from any of the positions above described, but the Rule on the next page applies equally to all of them; and even this does not differ *in principle* from the general rule (ELEMENTARY RULE, p. 85) as applicable to all drawings in cabinet perspective.

Fig. 11. In this figure we have drawn the ellipse within the cabinet square *A B C D*, in all respects like the ellipse of Fig. 10. The point *y* is the point from which we describe, with the compasses, the curve *3 w 21;* and from the point *z* we describe the curve *9 12 15.* These points are found in the same manner as the corresponding points for describing the ellipse of Fig. 10. Suppose this ellipse to be the upper horizontal end of a vertical solid cylinder forty inches in diameter. The distances *w 12* and *E F* therefore alike represent forty inches. Suppose the cylinder to be ten inches in height, and that we wish to draw the outline of the visible side of it toward the spectator. The cylinder will then extend downward from *E*, *w*, and *F*, five spaces, to *D*, *r*, and *C*. *E D* and *F C* will then be the vertical side lines of the cylinder; and through the points *D*, *r*, and *C* must be drawn the half of an ellipse corresponding in all respects to the curve *E w F*. As the rectangle *A B C D* represents the square inclosing the top of the cylinder, so the rectangle *E F G H* represents the square embracing the bottom of the cylinder; and if we describe a cabinet ellipse within this lower cabinet square, it will give the outlines of the bottom of the cylinder. Therefore

we describe an ellipse within the square *E F G H*, in the same manner that we described the ellipse within the square *A B C D*. The visible portion, *C r D*, of this ellipse, whose side curve is described from the point *p*, we have drawn with a firm line; the other portion, *D t C*, which would be invisible unless the cylinder were transparent, we have drawn with a slightly dotted line.

Fig. 12. Here the solid cylinder, the method of drawing which has been fully described in Figs. 10 and 11, is shown as completed and shaded. Any vertical cylinder, of any given dimensions, may be easily drawn by the method here described, and with such accuracy that all its parts may be readily measured.

Let it be observed that as the rectangle *A B C D* of Fig. 10 corresponds to the rhombus *A B C D* of Fig. 9, therefore the line *C B* of Fig. 10 measures the same (in cabinet perspective) as the *diagonal* line *C B* of Fig. 9; and *0 12* and *D A* of Fig. 10 the same as *0 12* and *D A* of Fig. 9, etc. Therefore we have the following rule for representing objects in *rectangular* cabinet perspective:

RULE.—*When, in drawing objects in* RECTANGULAR *cabinet perspective, a diagonal space is changed to a vertical space, the latter, when thus used to represent a horizontal distance, has the same measure as the former.*

Fig. 13. The upper part of this figure is drawn on the plan of Fig. 10 and Fig. 12. The lower part is a horizontal cylinder whose end directly fronts the spectator. Observe that the *length* of the horizontal cylinder, as measured from *1* to *2*, is sixteen inches; length of the short vertical cylinder only four inches.

PROBLEMS FOR PRACTICE.

1. Draw a vertical solid cylinder after the plan of Fig. 12, whose diameter shall be thirty-six inches, and whose axis, or length, shall be eighteen inches.

2. Draw a horizontal cylinder whose diameter shall be twenty inches, and length twenty-four inches, with one end directly fronting the spectator, as in Fig. 13; and at the farther end of this cylinder, and starting even

horizontal cylinder. The horizontal cylinder is to project forward from the front vertical side of a cube twenty inches square; and the vertical cylinder is to rise from the upper side of the same cube.

3. Draw a cube twenty-four inches square, in *right horizontal* rectangular perspective. Centrally placed on the right-hand side of it, extend out horizontally to the right another cube sixteen inches square; and on the right-hand side of this draw a horizontal cylinder twelve inches in length and sixteen inches in diameter. Shade all the front surfaces light, and the right-hand side surfaces dark. Then view the drawing as directed on page 50, except that the eye of the spectator should be *centrally* to the right of it. Also place the length vertically, and view it in that position until it seems to stand out boldly from the paper.

PAGE FIVE.—SCALE OF TWO INCHES TO A SPACE.

Fig. 14. It is required to make a drawing of the top of a hollow vertical cylinder eighty inches in extreme diameter, and whose sides are eight inches in thickness.

1st. Let *A B C D* be a rectangular cabinet square of eighty inches to a side. Within it describe an ellipse touching the centres of its four sides, after the manner shown in Figs. 10 and 11. Here *w* will be the point for describing the side curve *1 l 2;* and *x* for describing the other side curve *3 i 4;* while *t* and *s* are the points for describing the guiding circles for the outer end curves.

2d. Now, as the walls of this hollow cylinder are to be eight inches thick, the inner circle that bounds the walls on the inside must be eight inches within the outer circle; so we take *o r*, *k l*, *v p*, and *i j*, each eight inches within the ellipse first drawn, and complete the rectangular cabinet square *E F G H* eight inches, on all sides, within the outer square. Within this smaller square describe an ellipse touching the centres of its four sides, and we shall have the outlines of the top of the hollow cylinder, as required.

3d. This inner ellipse is drawn in all respects like the outer one. Thus *y* and *z*, found as before shown, are the points from which its side curves are described; and *m* and *n* are the points from which the guiding circles for drawing the ends of the ellipse are described.

4th. Observe that the walls of the cylinder *appear* the thinnest at the points *i j* and *k l*, and that at the points *o r* and *v p* they appear to be *double* the thickness of *i j* and *k l*, as they would naturally appear when viewed from the given point above and in front of the cylinder.

Fig. 15. It is required to make a drawing of a *thin* flat ring, forty-eight inches in diameter and four inches in width.

1st. Take the horizontal line *A B*, of twenty-four spaces, representing forty-eight inches, and on it construct the rectangular cabinet square *A B C D*. *A D* or *B C* will then represent forty-eight inches also.

2d. Describe the ellipse *1 2 3 4* within this square, and touching the centres of its four sides. This ellipse will represent the top circle of the ring. The central line, *4 2*, must be extended upward, so as to get the point from which the lower side curve is to be described.

3d. As the bottom circle of the ring is four inches below the top circle, it is to be described within a square four inches below the square which contains the top circle. Therefore lay off a second square, *E F G H*, four inches below the top square, and within it describe the ellipse *5 6 7 8*, touching the centres of its four sides at the points *5*, *6*, *7*, *8*. The outlines of the drawing, which may now be shaded, will thus be completed.

4th. Notice that *1 5* and *3 7* are straight vertical lines, representing the width of the ring, four inches; and that the curve *9 6 10* would touch the points *5* and *7* if it could be seen throughout.

5th. Observe that this ring is drawn as having no apparent or *measurable* thickness.

Fig. 16. It is required to make a drawing of a ring forty-eight inches in diameter, four inches in width (or height, as here viewed), and four inches in thickness.

1st. Draw the cabinet square, *A B C D*, of the requisite dimensions, and within it describe the ellipse, *1 2 3 4*, for the upper outer circumference of the ring.

2d. Take the cabinet square, *E F G H*, also of forty-eight inches to a side, four inches below the first-mentioned square, and within it draw an ellipse in all respects like the ellipse *5 6 7 8* of Fig. 15, with the exception that only the *front half* of the ellipse in Fig. 16, as denoted by the figures *5*, *8*, *7*, [illegible] the farther half being concealed by the thickness of the ring.

In order to get the actual thickness of the ring, take a cabinet square I J K L four inches within the square A B C D, and describe the ellipse 9 10 11 12, touching the centres of the four sides of this inner square. The thickness of the ring as seen on its upper horizontal edge will then be represented by the space between the two ellipses 1 2 3 4 and 9 10 11 12.

Now it is necessary to draw the inside portion of the lower outer circle of the ring. As this must be drawn four inches below the upper outer circle, take the cabinet square U V W X four inches below the square I J K L, and within it describe an ellipse touching the centres of its sides. Of this ellipse, a little less than the farther half, or part, will be visible.

There is then a *quadrangle* (four-sided figure) at each corner of the drawing. The two *outer* corners of *each* of the four quadrangles are the corners of the two cabinet squares within which the two *outer* ellipses are drawn; and the two *inner* corners are the corners of the two squares within which the two *inner* ellipses are drawn. Similar quadrangles may be found in the drawings of all cylinders on a rectangular basis, and these quadrangles are excellent guides for the formation of the squares within which the several ellipses are to be drawn. Observe that, in all similar drawings of hollow cylinders, the distance *A E*, or *B F*, or *C G*, or *D H*, represents the *height* of the cylinder.

The four ellipses described in this figure, representing the four circles that form the outlines of the *real* hollow cylinder, are all the guides that are required to draw any hollow cylinder, of any definite height, diameter, and thickness of walls, in the vertical position represented by a *rectangular* cabinet square, as distinguished from a *diagonal* cabinet square. A little practice will enable one to draw these ellipses with great facility, while the ruling of the drawing paper insures accuracy. These four *ellipses* answer to the four *circles* used in drawing a hollow cylinder [illegible] cabinet perspective.

Fig. 17 is the same in outline as Fig. 16, but is here shaded, the better to show the effect. Observe the four corner quadrangles, which are here retained as guides for the four cabinet squares within which the ellipses are to be drawn. The points from which the upper side curves are drawn are below the border of the page. Observe that the point *1* is the centre of the upper two squares and ellipses; and that the point *2* is the centre of the lower two squares and ellipses; while the line *1 2* represents the axis of the short cylinder or ring.

Fig. 18 represents the same ring as in Fig. 17, but with a portion of the front of the ring cut out vertically, and at right angles to its inner and outer surfaces.

PROBLEMS FOR PRACTICE.

1. Draw a vertical hollow cylinder whose extreme diameter shall be fifty-two inches; length of axis (height of cylinder), twenty inches, and thickness of walls, six inches.

2. Draw two *hollow* cylinders after the plan of Fig. 13, page 4. Let each of the cylinders be thirty-two inches in diameter, sixteen inches in length, and the walls four inches in thickness. Remember that it is to be drawn on a scale of "two inches to a space." This measure applies to both vertical and horizontal lines on the front end of the horizontal cylinder, while it means *four* inches to a space on lines *representing* horizontal lines running directly *from* the spectator. Thus, in Fig. 13, each of the lines *1 3*, and *4 5*, and *8 9* measures twelve inches; and *2 6* measures four inches; but *6 7* measures twelve inches, and *1 2* measures sixteen inches.

PAGE SIX.—SCALE OF TWO INCHES TO A SPACE.

Fig. 19. It is required to draw, in rectangular cabinet perspective, a hollow vertical cylinder, forty inches in extreme diameter, fourteen inches in height, the walls four inches thick, and to be encompassed by three bands, each two inches wide, one even with the top, one even with the bottom, and the third intermediate between the other two.

1st. Draw the hollow cylinder after the manner described in preceding figures. Referring to Fig. 19, let the pupil observe that it is the cabinet square *A B C D* that incloses the top of the cylinder, and the square *E F G H* that incloses the bottom. Hence *E* and *F* are fourteen inches vertically below *A* and *B*, and *H* and *G* are fourteen inches vertically below *D* and *C*, thus measuring two inches to a vertical space. And yet, when the line *A D* is taken as the *short visible side* of a rectangular cabinet square, and is considered as running horizontally *from* the spectator, being what is called *fore-shortened*, it is measured as *four* inches to a space, making the line forty inches in length. This principle must be kept carefully in mind, being equivalent to the principle of the measurement of "diagonal spaces" in Books No. II. and No. III.

2d. To describe the encircling bands. The principle is the same as explained in describing them in diagonal cabinet perspective; but we will show the application here in detail.

As *w* is the point from which, with the distance *w 4*, we describe the upper and outer side curve embraced in *1 4 3*, so, to describe the side curve of the lower side of the first band, we move the point of the compasses one space (two inches) downward, from *w* to *r*, and with the same stretch of the compasses as before describe the curve. Then, as the next band is four inches (two spaces) lower, we move the point of the compasses two spaces (four inches) downward, from *r* to *s*, and describe the upper side curve of the second band. So continue until all the bands are drawn. The *end* portions of the curves are drawn without the compasses, each to its given point on the side lines *1 5* and *3 7*.

We have also described six curves (portions of ellipses) on the visible inner side of the cylinder, between *m* and *9*, the better to show the curvature of the inner side of the cylinder. These curves are two inches apart; and the upper and the lower one are each two inches from the top and bottom inner curves of the cylinder. These curves are the same in form (so far as seen) as the upper curve *l m n*; and as the side portion of *l m n* is described from the point *z*, so, to describe the side portions of these six curves, carry the point of the compasses, at each remove, one space (two inches) downward below *z*.

Fig. 20 is the same cylinder as represented in Fig. 19, but is here drawn in *diagonal* cabinet perspective, after the manner shown in Book No. III. Observe that both cylinders measure the same, according to the principles of measurement applicable to each. Observe, also, that the two cabinet squares, *A B C D*, *E F G H*, of Fig. 20, correspond to the similarly lettered cabinet squares of Fig. 19.

Fig. 21. It is required to draw a horizontal wheel of the following dimensions in rectangular cabinet perspective: Wheel to be fifty-six inches in extreme diameter; horizontal thickness of rim, four inches; width of rim (or *height*, as it lies horizontally), two inches; a hub at the centre sixteen inches in extreme diameter, same vertical thickness as the width of the rim, and with a central eight-inch circular opening through it for the axle. There are to be eight spokes between the hub and rim, each four inches in horizontal thickness, and same vertical width as the rim, radiating from the centre of the hub, and at equal distances apart.

1st. Draw the upper and lower ellipses which form the boundaries of the rim in the manner described for drawing hollow cylinders in preceding figures.

2d. Draw the boundaries of the hub in the same manner.

3d. From the centre, *q*, with a radius of twenty-eight inches, describe a circle passing through the extreme points *o* and *t* of the wheel. Mark the points *w*, *s*, *p*, and *n* for the diagonals of the circle; then these points, together with the centrally dividing points *m*, *t*, *r*, and *o*, will divide the circle into eight equal parts. From each of the eight given points, beginning at *m* and moving to the left around the circle, lay off with the compasses any required distance, as *m 1* and *n 2*, and mark accordingly the points *1*, *2*, *3*, *4*, etc., for the positions in the wheel in which the spokes are to be represented. Then, as the spokes are to be each four inches in horizontal thickness, take with the compasses a width of two spaces, and lay off that distance on the circle from the points *1*, *2*, *3*, *4*, *5*, etc., and we shall have the distances *1 x*, *2 y*, *3 z*, *4 10*, etc., to represent the horizontal thickness of the spokes. From the given points draw the dotted lines perpendicularly toward the horizontally dividing line *o t*, and from the points where any pair of these dotted lines strike the outer upper ellipse of the wheel, draw lines to the corresponding *opposite* points of the ellipse, and the apparent upper surface width of the spokes will be given. Observe that the nearer these spokes approach, in lengthwise positions—lines running directly *from* the spectator, the wider their upper surfaces appear, and the narrower their side-views appear.

To get the apparent vertical thickness of the spokes, and the lines of their junction with the inside of the rim and the outside of the hub, we have only to draw lines vertically downward from the points where the upper lines of the spokes intersect the ellipses of the rim and hub, and then draw the lower lines of the spokes as shown in the drawing. The same result would be attained by supposing the spokes to extend through the rim, as shown by the dotted lines.

Fig. 22 is another illustration of the principles of dividing the ellipse into any number of equal parts, as set forth in Fig. 21.

It is required to make a drawing of a vertical tub, of the following dimensions, in rectangular cabinet perspective: The tub is to be twelve inches in outside height; forty inches in extreme diameter; having a bottom one inch thick from the level of the chimes below; its sides to be vertical, and composed of twenty-four staves of uniform width, and two inches thick; and the tub is to be encompassed by two hoops, each two inches wide, the upper one one inch from the top of the tub, and the other even with the bottom.

1st. Draw the hollow cylinder for the walls of the tub the same as in preceding figures, with the exception of the inside lower ellipse.

2d. Describe the semicircle, *6 0 6*, and with the compasses divide it into twelve equal parts. This is easiest done by commencing at *0*, and dividing each quarter—as from *0* to *3*, then from *3* to *6*, etc.—into three equal parts. This will give the corresponding points, *1*, *2*, *3*, *4*, *5*, *6*, on each side of *0*. From these points draw dotted lines vertically downward until they intersect the outer upper ellipse; also suppose these dotted lines to be extended until they intersect the nearer half of this outer upper ellipse. These twenty-four points of intersection with the outer ellipse will be the points of division for the apparent *outer* surface width of the twenty-four staves.

The top dividing lines of these staves must all be directed toward the centre, *q*, just as they would be in the real tub, and the intersections of these lines with the inner upper ellipse will give the points for the inside vertical divisions of the staves. It will be noticed that the staves diminish in apparent width from the vertical centre to the right and left sides, as their surfaces are seen more and more obliquely, but that they increase in apparent thickness, just as they would appear to do in viewing the real tub.

4th. Observe that the inside height of the tub, as measured from *7* to *8*, is only eleven inches, as required to be, while the outside height is twelve inches. Therefore the farther lower inner ellipse must be drawn one inch higher than it would be drawn if the tub had no bottom in it.

5th. Observe, also, that *A B C D* is the square within which the upper outer ellipse is drawn, and that *E F G H* is the square within which the lower outer ellipse is drawn. The distance apart—from *A* to *E*, etc.—depends upon the height of the cylinder. In Fig. 21 the distance is *two* inches, while here it is *twelve* inches. To prevent confusion of lines, the *lower* quadrangles only are here dotted.

6th. The hoops are to be drawn according to the method explained in Fig. 19. At the sides they should project, to the extent of their thickness, beyond the vertical side lines of the tub.

PROBLEMS FOR PRACTICE.

1 Draw a wheel similar to Fig. 21, but of the following dimensions: To be sixty-eight inches in extreme diameter; horizontal thickness of rim, two inches; width, or vertical height, of rim, six inches; a hub at the centre twenty inches in extreme diameter, same vertical height as rim, and with a sixteen-inch central opening through it for the axle. There are to be eight spokes between the hub and rim, each two inches in horizontal thickness, and same width vertically as the rim, radiating from the centre of the hub, and at equal distances apart.

2. Draw a tub similar to Fig. 22, but of the following dimensions: To be fifty-six inches in extreme diameter; sixteen inches in outside height; a bottom that comes up two inches from the level of the chimes below; its sides to be vertical, and composed of thirty-two staves of uniform width, and two inches thick; and the tub is to be encompassed by three hoops, each two inches wide—the upper one, one inch below the tops of the chimes; the lower one, even with the lower ends of the chimes; and the other, four inches above the lower hoop.

PAGE SEVEN.—SCALE OF THREE INCHES TO A SPACE.

Fig. 23. The same *crown-wheel* that is shown in Fig. 56, page 10, of Book No. III., is here drawn with its axis, *t s*, in a vertical position. The rectangles *A B C D* and *E F G H* represent the squares *A B C D* and *E F G H* of Fig. 56.

Here *w* is the centre of the upper horizontal surface of the wheel, across the ends of the cogs; and the wheel, as in Fig. 56, measures eleven feet in extreme diameter from *16* to *16*. From the centre, *w*, we therefore describe the two *ellipses* which give the thickness of the ends of the cogs, as in Fig. 56 we described the two *circles* from the corresponding centre, *w*.

Twelve inches below *w* we take the point *y*, from which, as a centre, we describe the two ellipses which determine the length of the cogs, and also the thickness of the wheel between their bases. Six inches below *y* we take the point *v*, which must be on the level of the upper surfaces of the four arms which support the rim; and from *v* as a centre we describe the ellipse which gives the limit for the ends of these arms at their upper extremities. As these arms are to be twelve inches in vertical height, or thickness, we take a point *x*, twelve inches below *v*, from which we describe the ellipse which limits the lower extremities of the arms, and also gives the inside lower boundary of the wheel.

As the axle on which the wheel turns extends fifteen inches beyond both the upper and the lower face of the wheel, the point *s* must be the centre of one end of the axle, and the point *t* of the other; and as the diameter of the axle is twelve inches, we have the dimensions of the ellipse described around *s* for one end of the axle. The other end, *t*, of the axle can not be seen.

The point *v* is the centre of the upper end of the hub, which is eighteen inches in diameter.

As the wheel is to contain thirty-two cogs, at uniform distances apart, and of the same width as the spaces between them, we divide each *quarter* of the *semicircle, 16 0 16*, into *eight* equal parts; and from the points of division on the semicircle draw lines vertically downward until they intersect the outer ellipse *16 17 16;* and the points of intersection will give the points for the divisions of the outer ellipse for the cogs and the spaces between them. From these points of division, lines, as *d w*, *a w*, etc., drawn to the centre, *w*, give the boundary-lines for the sides of the cogs at their ends. In a similar manner, lines drawn like *b y*, *g y*, *p y*, etc., give the boundary-lines for the sides of the cogs at their bases.

The four arms, or spokes, which support the rim are to be six inches in thickness, and twelve inches in vertical height, the same as in Fig. 56. Here we have placed these arms in diagonal positions, because they thus show to the best advantage; and the only remaining point now is to give the true representation for their thickness—six inches.

For this purpose, from *v*, the centre of the ellipse which passes through the extremities of the arms, we describe a circle (of which *u j* is a part) with a radius of sixty-three inches (the length of each arm from the centre, *v*). From the point *i*, where the diagonal *v i* intersects the circle, draw the vertical line *i r* to intersect the before-mentioned ellipse, and it will intersect it at *r*, on the *diagonal of the ellipse.* From the point *i* measure off, on the circle, with the compasses, *i h* and *i j*, each equal to one ruled space, and therefore each representing three inches; and from *h* and *j* draw lines vertically downward to intersect the ellipse. The space included between the points of the intersections of these lines with the ellipse will then represent six inches; and if lines be drawn from the points of intersection parallel to *r v*, we shall have the true apparent width of the upper surface of this one arm or spoke of the wheel. The true width of the others may be found in a similar manner; or it may be taken by the compasses, and applied to the other arms.

At *A* the method of drawing the *hub*, together with the arms radiating diagonally from it, may be more distinctly seen.

Let it be observed, here, with what perfect accuracy a line drawn vertically downward from the intersection of the circumference of a circle with its diagonal must intersect the ellipse drawn below it on the same diameter on *its* diagonal. Owing to this principle, any division, and any measurement, made on the circumference of the circle, according to whatever scale may be adopted, may be accurately represented on the ellipse.

Thus, in *B*, we have a circle, and within it a cabinet ellipse, both drawn on the same diameter, *m n*. Here *D B* is drawn on a diagonal of the circle, and *H F* on a diagonal of the ellipse. Observe, also, that every diagonal of the cabinet ellipse drawn like this, in a rectangle, is what we have called a *two-space* diagonal line, or a *semi-diagonal.* From the point *1*, where the circumference of the circle intersects its diagonal, draw a line vertically downward, and it will intersect the ellipse on *its* diagonal at the point *5*. Now the measure *1 4* is represented on the ellipse by *5 8*, and *1 2* by *5 6;* and if *1 4* is equal to two spaces, or six inches, and *1 2* equal to the same, then *6 8* will represent a distance of twelve inches; and the shaded band, *6 t s 8*, which extends across the ellipse, will be twelve inches wide. Remembering that the cabinet ellipse represents the circle viewed obliquely, we see why all measures on the circle must have their accurate representations on the ellipse. Also, we see from the three representations, Fig. 23, and *A*, and *B*, that *the diagonal of a cabinet ellipse must be drawn on a two-space diagonal line that passes through the centre of the ellipse.*

PROBLEM FOR PRACTICE.

Let the pupil, after drawing Fig. 23, draw another crown-wheel of any given dimensions that may be assigned.

PAGE EIGHT.—SCALE OF TWO INCHES TO A SPACE.

Fig. 24. It is required to make a drawing, in rectangular cabinet perspective, of a tub twenty-six inches in vertical height, forty-eight inches' extreme measure across the top, thirty-two inches' extreme measure across the bottom; the sides formed of thirty-two staves of equal width, and two inches in thickness, encompassed by two hoops, each two inches wide—one of them two inches from the top of the tub, and the other one inch from the bottom; the tub to

have a false bottom of one-inch stuff, seven inches in vertical height from the level of the top of the tub; and in the centre of this bottom an opening twelve inches square.

1st. Mark off the cabinet square, *A B C D*, forty-eight inches to a side, and within it, and touching the centres of its four sides, describe an ellipse for the upper outer circumference of the tub.

2d. Two inches within this outer ellipse describe another, and we shall then have the outlines of the top of the tub.

3d. From *m*, the centre of the top diameter, mark off *m n*, twenty-six inches, for the vertical height, or axis, of the tub. The point *n* will then be the centre of the bottom.

4th. With *n* for the centre, mark off the square, *E F G H*, of thirty-two inches to the side, and within this square describe an ellipse, only the nearer half of which, *1 2 3*, need be firmly drawn; and this part of the ellipse will give the visible portion of the outside circumference of the bottom of the tub.

5th. By connecting the extreme points *p 1* and *r 3* of the diameters of the upper and lower ellipses, the lines thus formed will give the side outlines of the tub; and if these lines be continued downward, they will meet in a point, *w*, on the downward continuation of the axis of the tub. All the *outside* dividing lines of the staves will tend toward this point, *w*, while the *inside* dividing lines will tend toward the point *z*, above *w*. The point *z* is found by drawing lines from *8* and *9* parallel to *p 1* and *r 3*, until they meet at a point in the downward continuation of the axis.

6th. Take the point 7, seven inches, on the axis, below *m;* and 7 will be the centre of the circle (or ellipse, in the drawing) which bounds the outer upper edge of the false bottom of the tub.

If the sides of the tub were vertical, we should measure off, from the inside top of the tub at the farthest point, *4 5*, equal to *m 7;* but as the line *4 5* extends downward toward the spectator, and is in reality longer than *m* 7, it must appear so in the drawing. The point *5* (when accurately found) must be in the middle point of the farther side of the cabinet square which bounds the ellipse that limits the false bottom of the tub, and which ellipse has *7* for its centre. To obtain, with accuracy, the point *5*, and the square within which this ellipse is to be drawn, draw the horizontal line from *7* toward *10*, and it will intersect a line drawn from *9* to *z* at a point *a*. The distance, *7 a*, will then be one half of the longer diameter of the ellipse which bounds this false bottom of the tub; and if *7 a* be twenty inches, we must so place the point *5* that the *horizontal* distance, *7 5*, shall also be twenty inches. We may thus easily construct the square within which the ellipse must be drawn. Centrally within the ellipse mark out the opening, twelve inches square, and give to the false bottom, on its farther side, a depth or thickness of one inch.

7th. The divisions showing the apparent width of the staves are obtained in the same manner as in Fig. 23.

Fig. 25. It is required to draw an octagonal tub (of eight equal sides), having an extreme upper diameter of forty-eight inches, a vertical height of twelve inches, a lower extreme diameter of forty inches, the sides two inches in thickness, and the whole resting on a two-inch thick octagonal bottom that projects two inches beyond the sides.

1st. Mark off the square, *A B C D*, of forty-eight inches to a side; and within it, and touching the centres of its four sides, draw lightly an ellipse, of which *i j k* is the farther half. As the central vertical line *j n* (*vertical* as seen on the paper, although it represents a *horizontal* line), the central horizontal line *i k*, and the two diagonals *A C* and *B D*, divide the circle represented by this ellipse into eight equal parts, so the intersections of these lines with the ellipse give us the eight corners of an octagon. Connect the points or corners thus found, and two inches within this octagon draw another in like manner, and we shall have represented the thickness of the walls of the octagon. This inner octagon may be drawn without first drawing its ellipse, simply by drawing its lines parallel to the surrounding octagon, and two inches within it.

2d. From *m*, the centre of the two ellipses and of the octagon just described, measure twelve inches vertically downward to *n*. Take *n 2* and *n 3*, each twenty inches, and on *2 3*, as the central horizontal line, mark off the cabinet square *E F G H*—*E H* or *F G* being half the length of *E F* or of *H G*. Within this square draw an ellipse touching the centres, *1*, *3*, *4*, *2*, of its four sides. Divide the nearer half of this ellipse so as to give the four nearer corners of an octagon, in the same manner as the upper octagon was formed. Connect the corners of this lower octagon with the corners of the upper octagon by the lines *i 2*, *n 4*, *k 3*, etc.

3d. Two inches within the lower square, *E F G H*, inscribe an ellipse, in the same manner that the inner upper ellipse was drawn, and find the corners *5*, *6*, 7 in the same manner that the corners *8*, *9*, *10* were found. Connect these lower corners with the upper corners. This inner octagon may be drawn by simply drawing its lines parallel to the outer octagon.

4th. Take *2 p* and *3 r*, each one space (two inches), and from *p* and *r* draw lines parallel to the border octagonal lines, and we shall have the projection of the bottom two inches beyond the walls of the octagon, thus forming an octagon two inches beyond the other; or this octagon may be formed by first drawing an ellipse on *p r* as a central base line. The two inches' *thickness* of the bottom, on which the octagonal tub rests, is easily designated by simply marking points one space down from the corners above.

Observe that the thickness of the walls of the octagonal tub, and the extension of the platform bottom, naturally appear the greatest on the extreme right and left sides of the drawing. Observe, also, that the farther *inner* side of the tub, as measured by the line *9 6*, appears deeper than the nearer side as measured by the line *n 4*. The cause of this is that the line *9 6* is more nearly at right angles to the line of vision than the line *n 4*.

III. ARCHES IN DIAGONAL PERSPECTIVE.

Figs. 26 and 27 are drawn in diagonal cabinet perspective; but it is the *upper left-hand view* of them that is here given, as explained on page 144, and illustrated at *D*, page 1, of Book No. IV.

Fig. 26. The lightly shaded portion of Fig. 26 represents the face of a pointed archway fronting the spectator, and is therefore drawn in its true relative proportions: the base line of the archway, *a d*, being thirty-two inches, and the height, *e f*, thirty-eight inches.

The outer curve line, *a f*, of the arch, is here drawn by the compasses, from a point twenty-six spaces—fifty-two inches—to the left of *a;* or it may be drawn from any other point that will give a graceful curve connecting *a* and *f;* but having drawn this curve, the opposite curve, *d f*, must be made to correspond to it. Then the inner curves, *p h* and *g h*, must be drawn from the same points from which the two outer curves were drawn, but each with a radius of twenty-four spaces. The curve *v h* must be drawn from a point twenty-four spaces to the left of the corner *v*.

As Fig. 26 is a front view of the arch, it is very easily drawn.

Fig. 27 is a diagonal view of the front of Fig. 26. Here the diagonal figure, *a b c d*, must measure the same as the corresponding rectangle of the preceding figure; and the curve *a f* must be drawn by hand, and be made to pass through points corresponding to those through which the curve *a f* of Fig. 26 passes. Thus the points *n* and *m* of Fig. 26 are respectively four and eight inches from certain points, *10* and *14*, in the corner line *a b;* and the corresponding points *n* and *m* of Fig. 27 must be similarly situated. So any point in any one of the curves of Fig. 26 should, if accurately drawn, have its corresponding point, by measure, in a corresponding curve of Fig. 27. This principle should apply accurately throughout the two figures—the measures from point to point in the one being the same (according to the principles of measurement) as the measures between corresponding points in the other. Thus the two points *n*, *n*, in Fig. 26 are each twelve inches horizontally distant from the point *w;* the corresponding points *n*, *n* in Fig. 27 are also each twelve inches (three diagonal spaces) distant from their intermediate point *w*. The under side of the arch must measure four inches, horizontally, in any part of it. So the outside of the arch, from *a r* to *f j*, must measure, in any part, four inches horizontally.

Having Fig. 26 as the pattern, and marking any required number of points in its curves, it is easy to mark corresponding points in Fig. 27, and draw the curves through them.

Fig. 28, drawn in diagonal perspective, consists of a rectangular box, open at top and bottom, thirty-two inches in outside width, sixty-four inches in length, thirty-four inches in height, and walls four inches thick, having an archway opening through both ends, and two archways on a side. The side archways are the same in size as those at the ends; and the face of the archway in the front end, being drawn in its true relative proportions, is the guiding pattern for drawing the others. Let the pupil describe the dimensions of the arch, method of drawing the side arches, etc. If the pupil will follow the directions given for Fig. 27, he will probably draw Fig. 28 with more accuracy than it is given in the book.

The principles here illustrated will be a sufficient guide for the drawing of all arches in diagonal perspective. First draw an arch of the required dimensions in its true relative proportions, with its face fronting the spectator: it will then be easy to make a diagonal view of the same arch—transferring the measures of the one to the other.

IV. SEMI-DIAGONAL CABINET PERSPECTIVE.

PAGE NINE.—SCALE OF TWO INCHES TO A SPACE.

In what has been called *Diagonal* Cabinet Perspective, a cubical block is supposed to be viewed in such a manner that the horizontal corner lines of the top and bottom of the cube that run *from* the spectator seem to rise diagonally at an angle of forty-five degrees—that is, half way from the horizontal to the vertical. Thus in Fig. 29, if the cube were drawn in *diagonal* cabinet perspective, its upper horizontal face would be bounded by the lines *1 2*, *2 3*, *3 7*, and *7 1;* and *5 4* would be its visible lower side line.

Now suppose that the eye of the spectator should be lowered so that the line *2 3* should be brought down and made to coincide with the line *8 9:* then *1 2* would be brought down to *1 8*, and *7 3* to *7 9*, and *5 4* to *5 10;* and thus the lines *1 8*, *7 9*, and *5 10* would be in the direction of *semi-diagonals*, or *two-space* diagonals, as shown in Book No. I., page 2. The front face of the cube would remain the same as in *diagonal* perspective; but the top and side would be changed as shown in Fig. 29. This is what is called "*Semi*-Diagonal Cabinet Perspective;" and it is specially adapted to the drawing of buildings or other large structures in full elevation, as hereafter shown.

In this modification of Cabinet Perspective, the principles of measurement remain the same as in the general system before explained. Thus, in *diagonal* perspective, the line *1 2*, according to the scale for the page, measures sixteen inches: but the line *1 8* must also measure sixteen inches: the line *1 2* extends from the point *1*, *diagonally*, to the *fourth* vertical line at *2;* and the line *1 8* extends from the point *1*, *semi-diagonally*, to the *fourth* vertical line at *8*—that is, the line *1 2* passes over *four* spaces, and the line *1 8* also passes over *four* spaces; and in each case a *space*—whether a diagonal or a semi-diagonal—measures four inches. If, therefore, we consider that each *semi*-diagonal (that is, the distance on the line *1 8* from one vertical line to another) measures the same as a *diagonal*, the rule of measurement is unchanged. The semi-diagonal cube, Fig. 29, therefore measures sixteen inches to a side, the same as the dotted diagonal cube.

Fig. 30 represents a cubical block, of twenty-four inches to a side, from each upper corner of which is taken away a cubical block eight inches square. There is an eight-inch square opening cut through the block, centrally, from the lower part of the front side; and also an opening of the same dimensions on the right-hand side.

Fig. 31 is a frame-work in semi-diagonal perspective. The central post measures eight inches square at the ends; and each *half* of it is thirty-six inches in length on each side of the cross-beam. The cross-beam is four by eight inches, and sixty-four inches in length, while the braces would measure four inches square at the ends if the ends were squared. Inasmuch as the side of the frame fronting the spectator is drawn in its true relative proportions, the same as *all* front views in the cabinet perspective of plane solids, therefore all lines, drawn in any direction whatever, on any portion of this front view, are measurable by the scale of two inches to a space. Hence the line *a b*, drawn at right angles across the brace, must be the true measure of the width of the brace; and, according to the scale, it is found to measure two spaces, or four inches. The line *c d*, being one semi-diagonal, measures four inches. We thus obtain the size of the timber used for the brace.

The extreme length of a brace, *1 3*, or its equal in length, *4 5*, may be found by actual measurement; for, as the line *1 3* is in a plane at right angles to the line of vision, it may be measured by the scale. Thus measured, it will be found that the line *1 3* is equal to twenty spaces—equal to forty inches. Or it may be measured by the rule for the extraction of the square root. Thus *1 2 3* is a right-angled triangle; and therefore, if we add together the squares of the sides *1 2* and *1 3*, and extract the square root of their sum, we shall get forty inches for the length of the line *1 3*. Try it.

Observe that the braces are flush with the *farther* side of the central post, and with the farther side of the cross-beam. The dotted continuations of the lines of the braces show the attachment of the braces to those sides of the post and cross-beam which are invisible to the eye.

Fig. 32 is the same as Fig. 31, but so placed that the front view of Fig. 31 is made the semi-diagonal view in Fig. 32. Let the pupil test all the measurements, and see that they are the same in both figures. Thus the line *6 7* in Fig. 32 measures the same, according to the principles of measurement adopted, as the line *6 7* in Fig. 31. Fig. 32, however, does not give so good a view of the frame as is shown in Fig. 31.

Fig. 33 is the same as Fig. 95 of Book No. II., but is here changed from diagonal to *semi*-diagonal perspective. Observe that, if the same scale be adopted, the measurements will be the same in both cases.

Fig. 34 is a hollow cylinder sixteen inches in length and eight inches in exterior diameter, having its walls two inches in thickness. The length of the cylinder may either be measured on its axis, A B, or any where semi-diagonally on its circumference—as on the line C D.

Fig. 33 is a cylinder eight inches in length and sixteen inches in diameter, having an opening eight inches square through it centrally lengthwise.

PROBLEMS FOR PRACTICE.

1. Draw, in semi-diagonal perspective, a cube thirty-two inches square, and also from the centres of each of its three visible sides a piece twenty-four inches square on the face, and four inches in thickness.

2. Draw a frame the same as Fig. 31, with the exception that the braces are to be placed flush with the front side of the central post and cross-beams.

PAGE XXI.—SCALE OF TWO INCHES TO A SPACE.

Fig. 34 represents a cube having a circle described on its top, and also one on each of its two visible sides, the whole being drawn in semi-diagonal perspective. The representative ellipse on the right-hand side of the cube is of the same width as in diagonal perspective, but not of the same proportions; but the ellipse on the top has only half the width that it would have in diagonal perspective. The front side being a square, the circle is there drawn *as* a circle, in its true proportions. See Fig. 29, and explanation, for the relative proportions of the three visible sides of the cube.

As the upper side of the cube is divided into the same number of semi-diagonal squares that the front side contains regular squares, the former representing the latter, therefore the ellipse drawn on the top must pass through the same corresponding points in the semi-diagonal squares that the circle passes through in the squares of the front side, on the principle that was explained in the drawing of Fig. 9. The ellipse on the top would be best drawn by first dotting the principal points through which it must pass, and then drawing the curve carefully by hand with a sharp-pointed hard pencil.

The ellipse on the side might be drawn by the same method, on the principle explained with reference to Fig. 9; but the side curves may be drawn with great accuracy by the process in the following manner:

1st. From the point *1*, the centre of the side *C F*, with the radius *1 B*, describe the indefinite curve *B 5*. 2d. From the point *B*, with the radius *B 2*, describe the curve *2 3*, intersecting the curve *B 5* at the point *3*. 3d. From the point *3*, with the radius *3 2*, describe the curve *2 4*. 4th. From the point *4*, with the radius *4 1*, describe the side curve *6 1 7*, which may be extended to within two inches of the line *C B* with accuracy.

5th. From the point *2*, the centre of the side *B E*, with the radius *2 F*, describe the indefinite curve *F p*. 6th. From the point *F*, with the radius *F 1*, describe the curve *1 n*. 7th. From the point *n*, with the radius *n 1*, describe the curve *1 m*. 8th. From the point *m*, with the radius *m 2*, describe the side curve *9 2 10;* which may be extended to about the point *11* with accuracy.

Thus the two side curves of the ellipse will be drawn, together with portions of the two end curves. The remaining portions of the end curves must be drawn by hand to the points *v* and *w*, taking care that they pass through points in the small semi-diagonal squares corresponding to the points through which the circle on the front passes. Let this figure be viewed intently through the opening formed by the partially closed hand, and the ellipses will soon take the appearance of perfect circles.

Fig. 37 represents a ring drawn in semi-diagonal perspective, and in the same position as shown by the ellipse on the right-hand side of the cube, Fig. 36. The inner diameter of the ring, as measured either by the line *v w* or *1 2*, is forty-eight inches, the same as the ellipse *1 v 2 w* of Fig. 36. The thickness of the ring is two inches, and its width four inches.

As the inner front ellipse is drawn within the semi-diagonal square, *C B E F*, so the outer elliptic circumference of the front face of the ring must be drawn within a semi-diagonal square two inches larger, in every direction, than the inner square, as shown by the surrounding dotted semi-diagonal square.

The true *width* of the ring is marked out by extending the points of the compasses two spaces, and laying off that distance horizontally to the left from the right-hand portion of the inner front ellipse, and also from the right-hand portion of the outer front ellipse. Thus the measurements 3 4, 5 6, 7 8, 9 10, etc., must each be equal in their lengths, if the ellipses be accurately drawn.

Fig. 38 represents a pointed arch drawn in semi-diagonal perspective. The opening, or span of the arch, 1 2, is forty inches; and the vertical height, 3 4, is also forty inches—although the arch proper is fourteen inches less in height, as the walls do not begin to converge until they reach a height of fourteen inches from the base.

If this arch were to be drawn from the given measurements, it should first be drawn within a rectangular square fronting the spectator. It could then be changed with accuracy to a semi-diagonal view, according to the method explained for transferring the measures of Fig. 26 to Fig. 27.

Or, if the nearer inner curve, 1 4, be drawn by the eye according to the judgment, the farther inner curve may be drawn to correspond to it. Then the outer curves, 5 6 and 5 7, must be made to correspond to the inner curves; and as 1 6 or 2 7 is a measure of four inches, so the point 5 must be taken four inches above the point 4. As the depth of the arch, 6 8 or 2 10, is six inches, so the depth, wherever measured on a horizontal line, as *a b*, *c d*, 11 12, 9 5, etc., must be six inches.

Fig. 39 is a cylinder one foot in diameter, and seven feet four inches, or eighty-eight inches, in length. Its axis is *a b*. At each end of the cylinder is a projecting tenon twelve inches long, eight inches wide, and four inches in thickness; and longitudinally through the cylinder is a mortise three inches wide, extending to within four inches of the ends, and coinciding in direction with the width of the tenons.

PROBLEMS FOR PLATE XIII.

1. Draw a pointed arch similar to Fig. 38, first in rectangular perspective, and then in semi-diagonal perspective, of the following dimensions: span of arch, forty-eight inches; height of opening, forty-eight inches; thickness of walls, eight inches; depth of arch, twelve inches. In the first drawing the front face of the arch is to be on a rectangular basis, and the figure in its relative proportions throughout, the side view is to be

in semi-diagonal perspective—just as the side view of Fig. 38 is in semi-diagonal perspective.]

2. Draw a partial cylinder, somewhat similar to Fig. 39, but of the following dimensions: Length of cylinder, eight feet; diameter, sixteen inches; tenons, sixteen inches in length, otherwise the same as in Fig. 39; upper side of the cylinder to be taken off horizontally, even with the top of the tenons; and a mortise, four inches wide and eighty inches in length, to extend longitudinally through the cylinder, equidistant from the two ends, and coinciding in direction with the width of the tenons, as in Fig. 39.

PAGE ELEVEN.—SCALE OF FOUR INCHES TO A SPACE.

Fig. 40. According to the scale of measurement adopted, Fig. 40 represents a small building, fifteen feet long, and ten feet eight inches wide, with posts nine feet four inches high. The four corner posts and sills are eight inches square at the ends; the two middle posts are four inches square, and the central cross-sill is four by eight inches. The plates on which the rafters rest are four by eight inches, while the rafters are four inches square. The rafters are placed at what is called *half pitch*—the height, *2 7*, being equal to half the span, *8 9;* or, as the vertical line *2 7* is equal to *2 8*, the rafters are at an angle of forty-five degrees.

Observe that the lower ends of the rafters come down at equal distances on both sides below the plate, as indicated by the line *5 6;* and that the ends are sawed off horizontally. The rafters are twelve inches apart, or sixteen inches between their central lines.

Observe that the *braces* are all of the same length—forty inches, inside measure—and that they are placed flush with the *outside* of the frame. Thus the inside of the top of the extreme brace at the right, at *s*, is twenty-four inches from the corner *t;* and the inside of the bottom of the brace, at *v*, is thirty-two inches below the corner *t*. Now, as *s t v* is a right angle, *s v* is the hypothenuse; and if we add together the squares of *s t* and *t v*, and extract the square root of the sum, we shall find that the length of *s v* is forty inches. All the braces are arranged in like manner. In all cabinet work, and in buildings, braces are generally arranged in the proportions of three measures for one side of the triangle and four for the other; and then five will be the measure [illegible] same, whether the measure be in inches or [illegible]

[illegible] difficulty in drawings similar to Fig. 40 con[illegible]g the braces in their correct positions, accord[illegible] the measurements assigned to them; and, in order to [illegible] them accurately, it is evident that we must first [illegible] those corners which are hidden from view, as shown [illegible] 31 and 32. The following problems will aid in [illegible]ing the principles which govern the drawing of [illegible] in the various positions in which they usually occur [illegible] building.

PROB[illegible]TICE.

[illegible] these problems the p[illegible] inches square at the ends; [illegible] plates or cross-beams [illegible] sixteen inches at the ends. [illegible]erring for illustration to the braces [illegible] top of each brace (as *s*) is be forty-eight inches, on the inside, from the corner (as *t*) where the ate joins the post; and the bottom of each brace, on the inside (as at *r*), to be *sixty-four* inches below the corner (as *t*) where the plate joins the [illegible]. The inside length of each brace will then be eighty inches. The es are to be twice the size of timber shown in Fig. 40, and to be placed with the *outside* of the frame. In each case, let the outlines of the concealed end of the brace be dotted, as in Figs. 31 and 32.]

1. Draw a brace of the given dimensions connecting a post and plate, as in the corner *A*. Only a sufficient length of post and plate may be drawn to show the plate to advantage.

2. Draw a brace for a corner corresponding to *B*.

3. Draw a brace for a corner corresponding to *C*.

4. Draw braces for corners corresponding to *D* and *H*.

5. Draw a square frame-work of two upright posts, and plate, and sill, corresponding to the left-hand end of the building, Fig. 40, and put a brace of the given dimensions, and flush with the outside, in each of the four corners of the frame.

6. Draw a brace for a corner corresponding to *G*, and also one for a corner corresponding to *I*, below *G*.

7. Draw braces of the given dimensions for corners corresponding to the four corners embraced by the sills of the building, and let the braces be flush with the tops of the sills. Let the sills be sixteen inches square at the ends.

V. SHADOWS IN CABINET PERSPECTIVE.

As cabinet perspective is designed for the *artisan* rather than the artist, we have thus far striven for no *effect* in our drawings beyond what is requisite to convey, in as simple a manner as possible, correct ideas of the forms and dimensions of objects. To this end such simple methods of plain shading have been introduced as will most readily distinguish one surface from another, while no attention has been given to the *shadows* cast by objects. But where it is desired to give greater artistic effect to cabinet drawings, the system of perspective here adopted will enable the draughtsman to define the outlines of shadows with the greatest ease, and with a degree of mathematical accuracy hitherto unattainable. On page 12 we give a few illustrations of the principles which are applicable to this subject.

PAGE TWELVE.—SCALE OF SIX INCHES TO A SPACE.

The objects here represented are supposed to stand on a horizontal plane, which may be understood to be the level surface of the earth; and the spectator is supposed to be looking down upon them from above, and at the right, and from a northerly direction. Hence the left-hand side of the paper is east, the upper side is south, the right-hand west, and the lower side is north—as indicated by the large capitals, E., S., W., N.

Fig. 41. This figure represents a square vertical pillar standing upon the level surface of the earth, while the sun, elevated at some distance above the horizon, and shining upon the pillar from a southeasterly direction, causes the pillar to cast a shadow on the earth, as shown in the drawing.

The sun is so far distant from the earth that the rays of light coming from it may be regarded as parallel. Suppose that the rays of light come from the southeast in a semi-diagonal direction, as indicated by the arrows, *a*, *c*, *e*; and that the ray *a*, just touching the corner *1*, strikes the earth at the point *9*. Then it is evident that all rays, such as *g h*, *i j*, etc., that strike the corner line *1 2*, will project shadows upon the earth between the points *2* and *9*; and hence the line *2 9*, which indicates a line of shadow drawn on the level surface of the earth, will be the shadow of the vertical corner line *1 2*. This line of shadow, *2 9*, although horizontal, will diverge away from the line *2 4*, and also be lengthened, just in proportion to the southerly direction of the sun, and its nearness to the eastern horizon. If the sun were directly east of the line *1 2*, and on the horizon, its shadow would be extended indefinitely from *2* in the direction of *2 4*; but the shadow would become shorter and shorter as the sun rose vertically toward the zenith; and when at the zenith the shadow of *1 2* would be contracted to a single point at *2*.

Hence two lines are required to define the shadow cast by the vertical line *1 2*: the one, *a 9*, called the *ray-line*, giving the direction of the ray of light that barely touches the corner *1*; and the other, called the *shadow-line*, drawn through the corner *2*, and intersecting the ray-line at *9*.

Hence, *to find the shadow cast on a horizontal plane by any given vertical line, or by any given point:*

RULE I.—*Draw a* RAY-LINE, *indicating the direction of the sun's rays, from the top of the given line to the horizontal plane which is on a level with the lower end of the given line; then draw a* SHADOW-LINE *from the lower end of the given line to the point where the ray-line strikes the horizontal plane. The shadow-line thus drawn will be the shadow of the given line.*

The shadow cast by any given POINT *on a horizontal plane may be found by first drawing a vertical line from it to the horizontal plane, and then finding the shadow of the given line, as before. The shadow cast by any required point in the given line may thus be obtained.*

Following out the principles of light and shade in connection with this rule, it will be seen, as before shown, that *2 9* is the shadow of the vertical line *1 2*, and that *9* is the shadow-point of the point *1*.

In a similar manner it is found that the line *4 8* would be the line of shadow cast by the vertical corner line *3 4*, if all the pillar except its corner line *3 4* were transparent; also that *6 7* is the line of the shadow cast by the corner line

5 6. The line *8 7* must therefore be the line of shadow cast by the line *3 5.* If *5 10* could cast a shadow, its shadow would be the line *7 11*, parallel to and equal in length to *5 10;* and if *10 1* could cast a shadow, its shadow would be the line *11 9*, parallel to and equal in length to *10 1.*

The following Rule may also be deduced from Fig. 41.

RULE II.—*Every horizontal line casts a shadow, on a horizontal surface, parallel to itself; and the shadow has the same representative length as the line casting the shadow.* Thus *9 8* is parallel to and equal to *1 3; 8 7* to *3 5; 7 11* to *5 10; 11 9* to *10 1*, etc.

Fig. 42. In this figure the horizontal lines of shadow cast on the ground by vertical lines are represented as bearing in the direction of southwestern four-space diagonals, as shown by the course of the arrows *a, b, c, d, e;* and the rays of light as coming diagonally downward, really *from* the northeast, as indicated by the arrows *f, g, h, i, j,* although they *seem* to come from the southeast. Here the north and east sides of the objects are in the light, and the south and west sides in shadow, as they would be if the objects were south of the equator, and the sun had risen midway toward the zenith.

Observe, here, that *4 m* is the line of shadow cast by *3 4; m n* the line of shadow cast by *3 1;* and *n v* a part of the line of shadow cast by *1 t;* and that *2 n* would be the shadow cast by *1 2*, if *1 2* could cast a shadow. Also, *6 13* is the line of shadow cast by the corner line *5 6; 14 15*, the shadow cast by *8 7; 15 16*, the shadow cast by *7 9;* and *16 17*, the shadow cast by *9 11.* The farther vertical corner line of the pillar, represented by the dotted line *11 12*, also casts a shadow on the top of the platform, which shadow is represented by the line *12 17;* but only a small portion, *17 x*, of this line of shadow is visible. Observe, here, the strict application of Rule II., as to the direction and length of the shadows cast by *horizontal* lines. Let the pupil explain the method of finding the shadow cast by any given line in Fig. 42, or by any given point in the structure.

Fig. 43. In this figure the north and west sides of the objects are in shadow; the horizontal lines of shadow cast

is not intercepted by the platform; and *9 8* is the shadow cast by *g d*. Now the shadow cast by the portion *g i* is evidently *i n*, which latter line is found by drawing a three-space diagonal line of shadow through the corner *i*, and intersecting it by the two-space diagonal ray-line *g n*. This completes the outlines of shadow cast by the platform and the pillar.

Fig. 44 represents two rectangular blocks, *A* and *B*, in vertical position, and standing at right angles to one another upon the horizontal surface of the earth. The sun is in the southwest, and at such an elevation that its rays pass downward in the direction of semi-diagonals, as indicated by the arrows *s*, *t*, *u*, *v*, *x*; while the shadows cast by vertical lines are in the direction of horizontal semi-diagonals, as indicated by the arrows *c*, *d*, *f*. Both blocks cast shadows upon the earth; while the block *B* casts a shadow, additionally, upon a part of the vertical surface of the block *A*.

In accordance with principles already explained, the line *2 g* is the shadow cast by the vertical corner line *1 2*. Having *g* as the point of shadow cast by the corner *1*, we know that the shadow cast on the earth by the line *1 7* would extend to the left from *g*, parallel to *1 7*, and of a length equal to *1 7*. But this line of shadow is intercepted at *9* by the vertical surface of the block *A*; and it is evident that *g 9* is the shadow of *1 10* only. Where, then, does the part *10 7* cast its shadow? As the point *10* casts its shadow at *9*, and as the shadow of *7* is at *7* itself, on the vertical surface of *A*, it follows that the straight line *10 7* must cast its shadow in a straight line from *9* to *7*, from which we deduce the following rule, applicable to all similar cases.

Rule III.—*The two points of shadow cast on a plane surface by the extremities of a straight line being given, the shadow of the line will be in a straight line connecting the two given points of shadow.*

The additional lines of shadow in Fig. 44 present no difficulties—the line *4 5* being the shadow of *3 4*, and *5 6* being the shadow of *3 i*. The line *i r* casts a shadow, and a part of it is out of view, on the farther or eastern side of the block *A*. But the shadow of the corner *i* is at *6*; and the

In this drawing the sun is supposed to be southwest from the spectator, half way between the zenith and the horizon; and hence the ray-lines are in the direction of diagonals, as indicated by the arrows *a*, *b*, *c*, etc.; while we assume that the lines of shadow cast by the vertical lines on horizontal surfaces are in the direction of three-space diagonals, as indicated by the arrows *e*, *f*, *g*, etc.

From the principles already explained, it is easy to find the shadows cast on the ground by the lines forming the ends of the steps; and the shadows cast by the block *Y* on the top of the first step, and on the riser of the second, are in all respects like the shadows cast, in Fig. 44, by the block *B* on the ground, and on the vertical side of the block *A*. It is evident, also, that the line *1 2* (a part of the vertical corner line *6 2*) casts its shadow on the top of the second step, from *2* to *3*.

Now the point *1* casts its shadow at the point *3*; and we find, in the following manner, that the point *4* casts its shadow at the point *5*. Take the point *m* in the line *6 2*, on a level with the top of the third step, and through it draw the indefinite shadow-line in the direction *m 5*. Through *4* draw a diagonal ray-line, and the point *5*, at which it intersects the line drawn through *m*, will be the point of shadow cast by the point *4*, in accordance with Rule I. But *5 3* is parallel to and equal in length to *4 1*—from which we derive the following rule.

RULE IV.—*The shadow cast, by a vertical line, on a vertical plane surface, is parallel to the vertical line itself; and, if the vertical plane surface have sufficient extent, the shadow will have the same length as the line casting the shadow.*

We next wish to find the shadow cast by the part *4 6* of the line *6 2*; and to this end we first find, in accordance with Rule I., the point of shadow cast by the corner *6*. Thus: we take the point *m*, in the line *6 2*, on a level with the top of the third step, and through *m* draw a line in the direction (*m 7*) of the shadows for vertical lines; and then through *6* draw a ray-line, which we find intersects the former line at *7*, thus showing that *7* is the point of shadow cast by the corner *6*.

We are next to find the shadows cast by the line *6 h*. According to Rule II., we find, as *7* is the shadow point of *6*, so *9* is the shadow of [illegible].

Also, referring to Fig. 44, we find, on the principles there explained, that as *7 9*, in Fig. 44, is the shadow cast by *7 10*; so, in Fig. 46, *9 11* is the shadow cast by *8 10*. Or, by taking the point *s*, vertically below *10*, and on a level with the top of the fourth step, we may show by the triangle *10 s 11*, that the point *11* is the shadow of the point *10* (Rule I.).

Again, by Rule II., *11 13* is the shadow of *10 12*. Also, according to the principle just referred to in Fig. 44, *13 15* is the shadow of *12 14*. And again, by Rule II., *15 17* is the shadow of *14 16*.

We have next to find the shadow cast by that portion of the line embraced between *16* and *h*. As *16* is the farthest point in the line *6 h* that casts its shadow on the steps, therefore *16 h* must evidently cast its shadow beyond the steps, on the ground. Let us, then, find the point of shadow cast by the corner *h*.

Take the point *n*, fifteen spaces vertically below *h*, on the ground-level; draw the three-space diagonal line of shadow through *n*, and the diagonal ray-line through *h*; and their point of intersection, at *j*, will be the point of shadow cast on the level ground by the corner *h*. Then *j i*, drawn parallel and equal to *h 16*, will be the line of shadow of *h 16*. The other portion of *h 6*, at the right of *16*, casts its shadow on the steps, as already shown; and at the point *i* its shadow is lost in the shadow of the steps.

The [illegible], equal and parallel to *h t*, is the shadow of [illegible] would be the shadow of the farther vertical [illegible] corner line *t u*; but only the portion *x z*, of [illegible] shadow-line, can be seen. Observe, also, that as the [illegible] passing through *16* just touches the point *17*, and [illegible] ground at *i*, and as *r* is the point of shadow cast [illegible] *i r*, equal and parallel to *17 p*, must be the [illegible] on the ground by [illegible]. So accurately do all the shadows harmonize with one another, and beautifully illustrate the principles of shadows, as deduced from this system of drawing.

The shadows cast by curvilinear objects may be defined with equal accuracy, on the general principles already explained, with some modifications; but we have not space to illustrate the subject here.

APPENDIX.

ISOMETRICAL DRAWING.

I. ELEMENTARY PRINCIPLES.

Isometrical Drawing, or *Isometrical Perspective*, is based upon the following principles: If a cubical block, as shown in Fig. 1, Plate I., and as seen shaded in Fig. 2, be supposed to be viewed from an infinite distance, and from such a position that the *line of vision* shall pass through the upper and nearer corner, *1*, and also through the lower farther corner, the three visible faces, *A*, *B*, *C*, of the cube will appear to be *equal in measure*, the one to the other. Any boundary-line of the upper surface, *A*, will measure the same as any boundary-line of the face *B*, or of the face *C*. Thus the line *1 4* will measure the same as the line *1 6*, or *4 5*, or *6 5*, or *1 2*, or *2 3*, etc. And any *measure* taken on any one line will give the same relative distance when applied to any other line. Hence the appropriateness of the term *Isometrical*, which is formed from two Greek words signifying *equal in measurement.*

The isometrical cube is based upon the geometrical principle for inscribing a hexagon in a circle. Thus, to inscribe a hexagon in the circle, Fig. 1, take the radius, *1 4*, and, beginning at *2*, apply it six times to the circumference, and it will give the points *2*, *3*, *4*, *5*, *6*, *7*. Join these points by straight lines, and we shall have the six equal sides of a regular hexagon. Connect the alternate corners of the hexagon with the central point, *1*, and retain the circumference of the circle, and we shall have the isometrical cube inscribed in a circle.

[illegible] isometrical cube which is supposed to stand upon [illegible] surface while the spectator looks down upon it [illegible] of the lines 2 3 and 2 7 forms an angle of [illegible] with the vertical line 2 1, and an angle of [illegible] degrees with the horizontal line 8 9. It will be observed [illegible] the lines 1 4 and 6 5 are parallel to 2 3; 1 6 [illegible] parallel to 2 7; 3 4 and 7 6 parallel to 2 1. In the isometrical cube, therefore, and in all isometrical drawings, there are only three kinds of *true* isometrical straight lines—vertical lines, and the two kinds of diagonals as seen in Fig. 1. But unless the diagonal lines form *exact* angles of sixty degrees with the vertical lines, the drawings made on them will be distorted; and as these lines can not be made with sufficient accuracy with the pen or pencil, we have had them accurately engraved, and printed in red ink on drawing-paper. By the aid of such paper all difficulty in making accurate isometrical drawings is now removed, as the ruling is a perfect guide for the direction of all the diagonal lines; and the vertical lines, as will be seen, follow the intersections of the diagonals.

Let it be observed, also, that the *diagonal* distance from point to point in the intersections of the diagonal lines is precisely the same as the *vertical* distance between their intersections. Thus, in Fig. 1, the five diagonal spaces from [illegible], or 2 to 6, or 3 to 7, etc., measure the same as the five vertical spaces from 2 to 3, or 1 to 4, or 6 to 7, etc. Moreover, the *Isometrical Drawing-Paper* is so ruled as to correspond, in measure, to the ruling of the *Cabinet Drawing-*[illegible] what is called *a space* in the one corresponding to [illegible] the other. From the foregoing explanation, the [illegible] familiar with the principles of cabinet perspec-[illegible] making every variety of [illegible]

II. FIGURES HAVING PLANE ANGLES.

PLATE I.—SCALE OF TWO INCHES TO A SPACE.

According to the scale here adopted, Fig. 1 represents the outlines of a cube of ten inches to a side, and Fig. 2 is the same, shaded. The student will notice the difference between the mode of measurement here adopted and that used in cabinet perspective. In the latter, also, one face of the cube—the front vertical face—would be drawn in its natural proportions, as a perfect square.

Fig. 3 represents a cube of ten inches to a side, having rectangular pieces six inches square and two inches in thickness cut from the centres of its three visible faces. Let the pupil compare this drawing with that of Fig. 12, page 1, of Drawing-Book No. II. The cube shows to excellent advantage in isometrical drawing.

Fig. 4 represents an inverted frame sixteen inches square, with corner posts two inches square and six inches in length.

Fig. 5 is the same as the English cross bond shown in Fig. 38, page 4, of Drawing-Book No. II. The two figures illustrate, very happily, the two methods of representation —cabinet and isometrical. The scale adopted being the same in both cases, the bricks measure the same in both.

Fig. 6 is the same as the upper part of Fig. 88, page 11, of Drawing-Book No. II. A figure of this kind, evidently, does not show to so good advantage in isometrical as in cabinet drawing. The former is best adapted to the representation of objects whose side views are nearly equal in proportion.

PROBLEMS FOR PRACTICE.

We would now recommend the pupil to draw, in isometrical perspective, all the figures given on the first five pages of Drawing-Book No. II. Let him take the measures as there indicated by the scale, but let him remember that a *diagonal* space is there to be taken as twice the length of a vertical or horizontal space, while in isometrical drawing a diagonal space and a vertical space measure the same, and are to be considered of equal length.

The pupil would do well to draw all the *problems*, also, connected with these first five pages.

PLATE II.—SCALE OF ONE FOOT TO A SPACE.

We have here adopted a scale of one foot to a space, although any scale whatever, that is most convenient, may be used.

Fig. 7 is intended to represent the upper part of a pillar five feet square, around which a moulding of one foot projection and one foot in height is to be placed, even with the top. The shaded portion shows the attachment of the moulding to the pillar.

Fig. 8 shows the moulding as attached, and concealing from view a portion of the pillar down to the line *8 9 10*. Hence the following rule:

RULE.—*Any horizontal rectangular moulding attached to a vertical surface obstructs the view of that surface below the moulding to an extent equal to the extent of the projection of the moulding.*

Fig. 9. The dotted outline represents a cubical block four feet square, while the shaded portion shows a wedge cut from it. The sides of the wedge bevel off equally from the sharp edge *1 2*, inasmuch as the lines *1 4* and *1 5* intersect the base line *4 5* at equal distances from the point *3*.

Fig. 10. The pillar in this case is of the same size as that seen in Fig. 8; but in Fig. 10 the moulding is cut up into three cubical blocks on a side, each one foot square.

Fig. 11 shows how triangular blocks attached to the top of a column may be represented. The dotted continuations of the lines of the farther two blocks show the concealed points on the column toward which the lines are to be drawn.

Fig. 12 represents a truncated pyramid, the base of which is surrounded by rectangular mouldings. Observe that the side lines of the pyramid are drawn toward the point *x*.

Fig. 13. Very tall four-sided pillars, gradually tapering, and having a flat pyramid at the summit, as at *A* and *B*, are called obelisks. Observe that the apex, in these two obelisks, is in the central vertical line of the pyramid.

Fig. 14. This pyramid has a rectangular section, one foot in depth, cut from each of the two visible sides of the base,

and triangular sections cut *through* the pyramidal portion, so that all except the four edges of the pyramid, and one foot in thickness of its base proper, are cut away. The farther edge of the pyramid is concealed by the front edge.

PLATE III.—SCALE OF TWO FEET TO A SPACE.

Although any object drawn isometrically is supposed to be viewed in the direction of the diagonal of a cube, yet we may view any one face of a cube, or any one side of any rectangular object, from four different positions, and at the same time view it in the direction of some one of the diagonals of a cube. Thus:

Fig. 15 represents a block viewed in the direction of the diagonal that passes through the corner *1*. We here see the top, front, and *right side*.

Fig. 16 represents the same block viewed in the direction of the diagonal that passes through the corner *2*. We here see the top, front, and *left side*.

Fig. 17 represents the same block viewed in the direction of the diagonal that passes through the corner *4*. We here see the *bottom*, front, and *right side*.

Fig. 18 represents the same block viewed in the direction of the diagonal that passes through the corner *3*. We here see the *bottom*, front, and *left side*.

Figs. 15 and 16 are viewed from above, and 17 and 18 from below. These are similar to the different views of objects in cabinet drawing, as represented on page 1 of Drawing-Book No. IV.

Fig. 19 is the same as Fig. 56, of page 7, in Drawing-Book No. II., although the designated scales are different. By adopting the same scale, the figures will measure alike.

Fig. 20 represents two flights of steps, ascending in different directions, and leading to a platform seven feet in height. As each step rises half a space—that is, one foot, seven steps are required to reach the platform.

Fig. 21. The upper roof, *A*, of this structure is evidently horizontal. The second portion, *B*, declines downward from the horizontal, as represented by the extent to which the line *1 3* diverges downward from the diagonal horizon-

The curve *B D* will thus be divided into three equal parts, representing angles of thirty degrees each at the point *A*. Next divide each of these parts, by the compasses, into three equal portions, and the entire curve will then be divided into nine equal parts, of ten degrees each. Through these points of division draw lines from *A*, and extend them to the sides *B C* and *D C* of the square. Draw a dotted line from *A* to *C*, and the angle *D A C* will be half a right angle—that is, an angle of forty-five degrees, while each of the angles *D A 10*, *10 A 20*, *20 A 30*, etc., will be an angle of ten degrees.

Within the larger square, *A B C D*, we may count twenty-five different squares, each having one of its angles at *A;* and on the two sides of each of these squares, opposite *A*, we have the same degrees marked off, by the lines diverging from *A*, that we have on the sides *B C* and *D C* of the larger square. Thus the measure *8 p*, on the side of a square of eight spaces, measures an angle of twenty degrees at *A*, as truly as the measure *D 20* measures the same angle; and *8 r* measures an angle of forty-five degrees, just as effectually as *D C* measures the same angle.

Now, inasmuch as any one of the twenty-six rectangular squares that may here be designated exactly measures an isometric square of the same number of spaces to a side, the measures of angles on any one of these rectangular squares may be used to lay off like angles on a corresponding isometric square. Thus:

Fig. 23. It is required to lay off, from the point *1* in the line *1 2*, an angle of ten degrees. As the lines *1 2* and *2 3* are two sides of an eight-space isometric square, they correspond to the two lines *A 8* and *8 r* (in Fig. 22), two sides of an eight-space rectangular square, and measure the same. From the point *8*, on the line *A D*, take the distance *8 a*, and apply it to the isometric square on the line from *2* to *3*, and mark the point *5*. A line drawn from *5* to *1* will then correspond to the line *a A;* and the isometric angle *5 1 2* will correspond to the angle *a A 8*, and will represent an angle of ten degrees.

If from the point *4*, in the line *4 3*, of the isometric square

APPENDIX.

[illegible] twenty [illegible]
[illegible] drew [illegible]
[illegible] isometric and [illegible]
[illegible] twenty degrees.
[illegible] twenty degrees from the [illegible]
[illegible] and comes [illegible]
[illegible] twenty degrees.
[illegible] twenty degrees [illegible]
[illegible]
[illegible] the five-sided figure
[illegible]

[illegible] rectangular square.
[illegible] isometric square. [illegible] measure from the [illegible]

[illegible]

IV. THE ISOMETRIC ELLIPSE AND ITS APPLICATIONS.

The *Isometric Ellipse* is the ellipse which is drawn within an isometric square, touching the middle points of its sides, as the three ellipses in Fig. 26, Plate V. The isometric ellipse represents a circle viewed in the position of a side of an isometric cube.*

Fig. 26. *Plate V.*—Here is represented a cube which measures ten spaces to a side, and on each of its three visible faces is an isometric ellipse which represents a circle drawn touching the middle of the sides of the inclosing square.

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and angles at *4* and *6*, up to forty-five degrees, may be laid off on the side *5 3*. So angles at *3* and *1*, up to forty-five degrees, may be laid off on the side *2 4;* and angles at *2* and *4*, up to forty-five degrees, may be laid off on the side *1 3*. Angles for the front face may be laid off on all the sides of that face. But to lay off an angle at *6*, on the line *3 4*—although the measure *3 4* would make the angle *3 6 4* one of forty-five degrees, yet for lesser angles we should be obliged to take *such proportions* of *3 4* as the measures for angles, on the scale, bear to the entire side of the rectangular square from which the measures are taken. It would be the same when an angle at *4* or *3* should be required to be laid off on the side *1 2;* or an angle at *1* or *2* should be required to be laid off on the side *3 4*.

The same principles apply to the laying off of angles in *semi-diagonal* cabinet perspective. See pages 10 and 11 of Drawing-book No. IV. Yet, for practical purposes in all working drawings, the true angles, or inclinations of lines, can generally best be laid off by some known measurements on the objects themselves.

* *Note.*—In the isometric ellipse, what is called the major axis (greater diameter) is a little more than once and seven tenths the length of the minor axis; and it is of the same length as the diameter of the circle which the ellipse represents. Thus, in Fig. 26, the upper ellipse represents a circle whose diameter is *s t*—that is, it represents the *outer* circle of Fig. 27, Plate VI., while the *inner* circle of Fig. 27 is the one we are obliged to compare it with in prescribing the rules of practical isometrical drawing. The reason of this is that the square within which the circle is drawn is diminished in apparent length of sides by an isometrical view of it; and we adapt the scale of our drawing to the *apparent* size, and not to the real size. Hence we draw a rectangular square, as *A B C D*, of Fig. 27, having the same *real* length of sides as the *apparent* length of the sides of the isometric square, *A B C D*, of Fig. 26; and then any lines, divisions, or points of the one may have corresponding lines, divisions, and points in the other. That is, both may be drawn *to the same scale;* and one may be used to illustrate the other. Thus the two kinds, cabinet and isometrical drawing, perfectly harmonize in measurement.

[illegible]

[illegible] the

[illegible] Isometric Ellipses.

[illegible] addition to the na- [illegible] *isometric diame-* [illegible] 27 or 4 26 is the [illegible] being central- [illegible] sides of the inclos- [illegible] The isometric diameter is equal to a [illegible] of the isometric square. Hence, when an isometric square is laid down on isometrically ruled paper, the isometric diameter of the ellipse that may be drawn within it is also known and may be found by merely counting the [illegible]

The proportions which the minor axis, the major axis, and the isometric diameter bear to one another are also known; and a table of these relative proportions is given on page 205. We have also prepared, in Fig. 28, Plate VI., a *diagram scale*, in which the proportions are given, *by measure*, for ellipses of any size up to one whose isometric diameter is not more than thirty-five spaces of the isometric ruling given on the isometric drawing-paper. The scale, however, may easily be extended to any required size.

Fig. 28. *Plate VI.*—To illustrate. The scale is made in the following manner: Take a rectangular square of any equal number of spaces to a side, as *A B C D*. From one corner, as *D*, with a radius *D B*, cut the side *D C* extended, in *E*, and join *E A*. From the points where the vertical ruled lines from above intersect the line *A E*, draw horizontal lines to the line *A D*. These thirty-five horizontal lines, thus drawn, measuring from one space up to thirty-five spaces, represent the *isometric diameters* of that number of ellipses, while to each isometric diameter is assigned its proper major axis and minor axis.

Thus, if the isometric diameter of the ellipse be the line *D E*, its major axis will be *A E*, and its minor axis *A D*. Again: if the isometric diameter of a required ellipse be twenty spaces, its measure will be the horizontal line from the point *20*, on the diagonal line *A E*, to the line *A D;* its major axis will be the measure from *20* to *A;* and its minor axis will be the measure from the point *A*, down to the intersection of the line *A D*, with the horizontal line drawn from *20*. Or, what is the same thing, the minor axis will be the measure from the point *20* up to the point *t* on the line *A B*.

Fig. 26. *Plate V.*—Application. Suppose that, in Fig. 26, we have merely the isometric square *A B C D*, of ten spaces to a side, and wish to draw within it an isometric ellipse touching the middle points of its four sides. The isometric diameter being *7 1* (or its equal, *B C*), we observe that it is represented by the horizontal line on the scale, Fig. 28, from *10*, on the diagonal line *A E*, to the vertical line *A D*. The line *10 A* is, then, the major axis of the el-

[illegible]

[illegible]

[illegible]

[illegible]

The ellipse of Fig. 29 may be considered the upper end of a vertical cylinder, having an axis, *c 2*, of thirteen feet, and a diameter, *1 7*, or *4 10*, of ten feet. The side lines, *t 3* and *s 5*, are drawn the same as the side lines of vertical cylinders in cabinet perspective, while the ellipse for the bottom—only half of which is visible—is drawn within the isometric square, *E F G H*, in the same manner as the upper ellipse. The side curves on the cylinder are described from points below *w*, by continued removals of two spaces downward, and all with the same stretch of the compasses, *w v* or *w 4;* while the end curves are described in a similar manner, from points vertically below *y* and *n*.

Fig. 30 is an ellipse representing a circle of only five spaces' (five feet) diameter, described on the top of a vertically placed block; and Fig. 31 represents one of the same dimensions on the end of a horizontally placed block. Fig. 32 represents a cylinder, six feet in diameter and three feet in length, placed horizontally, the end of it being in the same position as the ellipse on the left-hand side of Fig. 26. Fig. 33 is a cylinder of the same dimensions as Fig. 32, but the visible end of it is in the position of the ellipse on the right-hand side of Fig. 26. The upper part of Fig. 34 represents a vertical cylinder, two feet in diameter and four feet in length, cut from a block two feet square at the end.

PLATE VII.—SCALE OF ONE FOOT TO A SPACE.

Fig. 35 represents a hollow cylinder, fourteen feet in extreme diameter, four feet in height, and having its walls one foot in thickness. It will be seen that its upper outer ellipse is drawn within the isometric square *A B C D*, and that the inner ellipse is drawn within a square one foot within the outer square. The farther inner bottom curve must, evidently, be drawn within a square of the same dimensions as the upper inner square.

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ther from the centre, *c*, than those we have given, while those for describing the end curves would be a trifle *nearer* the centre, *c*, than those we have given. But this method would require one half of the side curves of the ellipse to be drawn without the aid of compasses; and the result would seldom be as accurate as by the method we have given.

Fig. 36 illustrates a method of dividing the ellipse into any number of equal parts, or of making in it any required divisions.

From *E*, the centre of a side, *A B*, of the isometrical square which incloses the ellipse, draw *E D* at right angles to *A B** and equal to *E A*. Connect *A D* and *B D*. From *D*, with any radius, the greater the better, describe a curve, *2 3*, cutting the lines *B D* and *A D*. Mark this curve according to the divisions required in *A c D*, one quarter of the ellipse, and through the points of division draw lines from *D* to the line *A B*. From the intersections of these lines with *A B* draw lines to the centre, *c*, of the ellipse, and the quarter part of the ellipse will be divided in the same proportions as the curve *2 3* is divided. Here the curve *2 3* is designed to be divided into eight equal parts—four parts on each side of the central point *E*; and hence one quarter of the ellipse is divided into the same number of equal parts. If the same divisions are to be continued throughout the ellipse, transfer the points of division on *A B* to the other sides of the isometric square, and from them draw lines to the centre, *c*, etc.

Or the method given in Figs. 21, 22, 23, and 24, of Drawing-Book No. IV., may be adopted for all isometrical ellipses.

V. MISCELLANEOUS APPLICATIONS.

Fig. 37. To draw an isometrical octagon within an isometrical square. And, 1st, when one of the sides of the octagon is to coincide, in part, with the sides of the isometrical square:

Within the isometrical square lay down the points *1 2* and *3 4* (taken from diagram, Fig. 28) for the extremities of the major and the minor axis of the ellipse to be drawn within the square. Then through these points draw lines at right angles to the two axes, and the lines thus drawn will be four of the sides of the required octagon. The other four sides will be those portions of the sides of the isometric square lying between the intersections of the first four lines. It will be seen that the ruling of the paper is a perfect guide for drawing lines at right angles to the major and the minor axis.

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* If the line *E D* be drawn from *E* in the direction of two-space diagonals, it will be at right angles to *A B*.

2d. When the centre of each of the four sides of the isometric square is to be touched by an octagonal corner.

Draw two lines from each extremity of the major and minor axes to the centres of the two sides adjacent each extremity, and the octagon will be completed. Thus draw lines from *2* to *5* and *6*, from *4* to *5* and *8*, from *1* to *7* and *8*, and from *3* to *6* and *7*. Inner lines may easily be drawn parallel to the outer lines.

Fig. 38 is an octagonal tub or box nine and a half feet in vertical height; and the sides, one foot in thickness, bevel outward from the top downward. The top is inclosed by an isometrical square of ten feet to a side, and the bottom by a square of thirteen feet to a side. The figure itself will sufficiently explain the method of drawing it.

PLATE VIII.—SCALE OF ONE FOOT TO A SPACE.

Fig. 39 shows that the half of a cylinder, of three-feet radius, cut longitudinally and vertically, has been *taken from* a piece of timber measuring at the upper end four feet by six feet. The hollow in the timber is semicircular, but shows here as the half of an isometric ellipse, viewed in the position of the ellipse on the right-hand side of the cube in Fig. 26.

Fig. 40 represents a semicircular arch of twelve-feet span in its extreme measure from *2* to *3*, five feet in length, and with walls two feet in thickness. The arch shows the upper halves of two isometric ellipses, each viewed in the position of the upper half of the ellipse seen on the right-hand side of the cube in Fig. 26. The outer ellipse is drawn within an isometrical square of twelve feet to a side, and the inner ellipse within one of eight feet to a side. The farther curve is part of an ellipse like the outer front ellipse. The method of drawing the lines for the uniform layers of

[illegible]

[illegible]

[illegible]

[illegible]

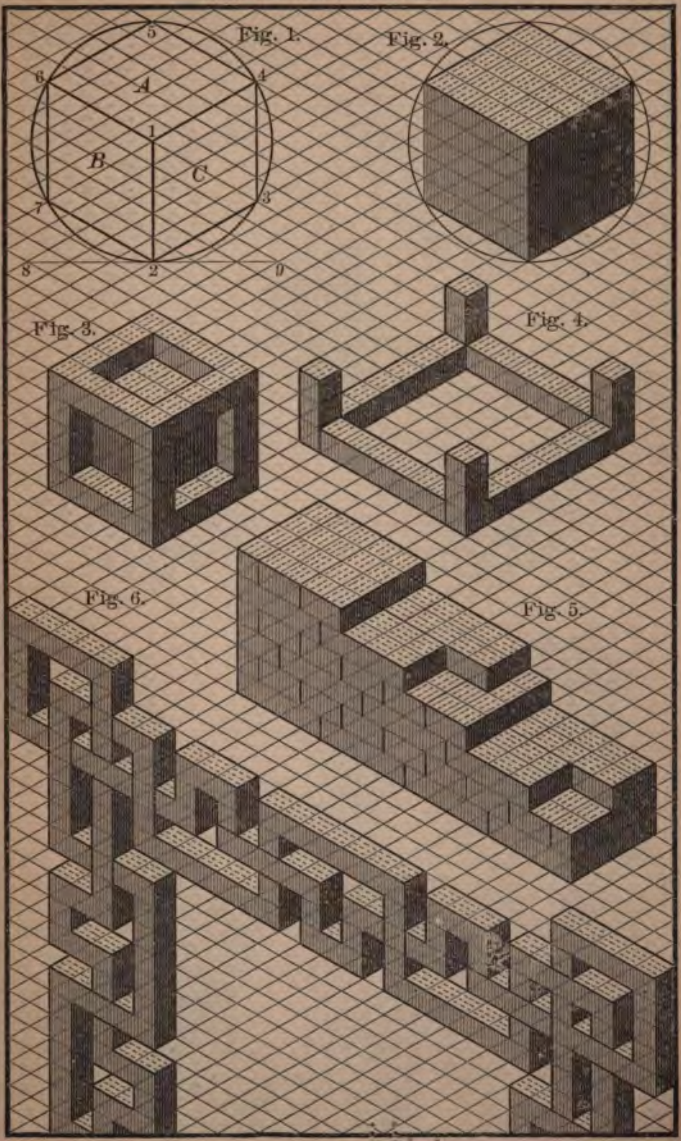
[illegible] geometrical draw- [illegible] the former

TABLE FOR DRAWING CIRCLES IN ISOMETRICAL PERSPECTIVE.

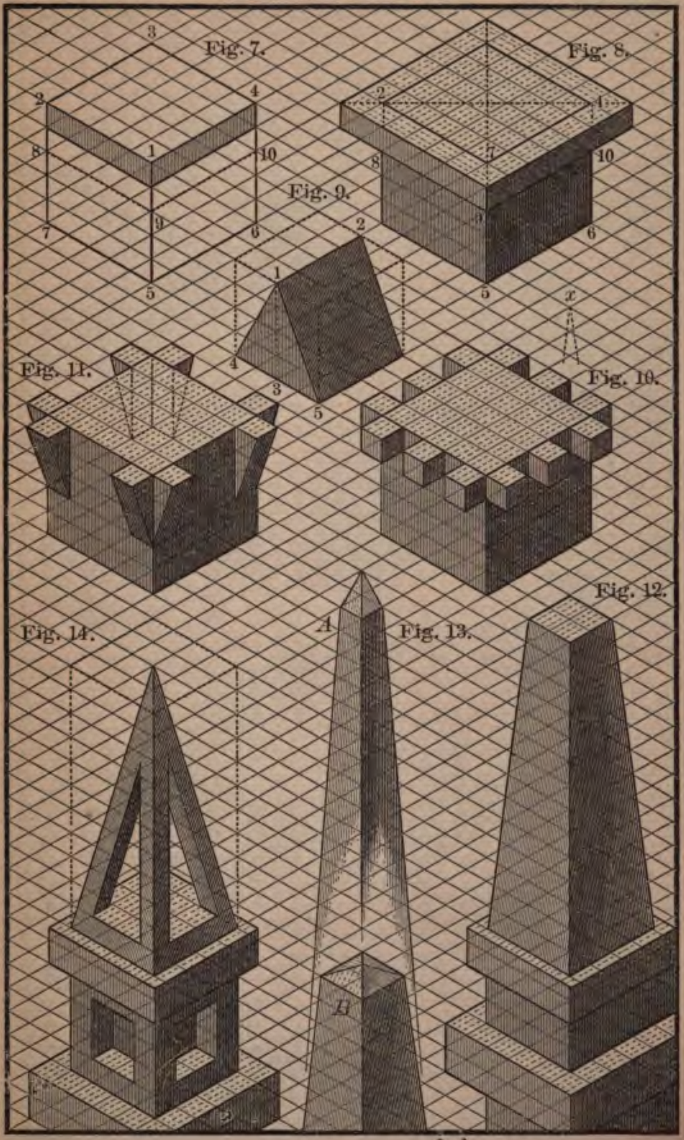
The figures in the columns of Isometrical Diameters denote the lengths of isometric diameters (or sides of isometric squares); and the figures in the other two columns denote the corresponding lengths of the minor and major axes. Thus, if an ellipse is to be drawn in an isometric square of 10 spaces to a side, the isometric diameter will be 10 spaces in length, the minor axis will be 7.071 spaces in length, and the major axis 12.247 spaces in length. The Table gives the relative proportions of the isometric diameters, minor axes, and major axes for all isometric ellipses drawn in isometric squares of from 1 to 90 spaces in diameter. The principle holds good whatever measure of length the figures in the columns of Isometrical Diameters represent.

Isom. Diam.	Minor Axis.	Major Axis.	Isom. Diam.	Minor Axis.	Major Axis.	Isom. Diam.	Minor Axis.	Major Axis.
1	.707	1.225	31	21.920	37.967	61	43.134	74.709
2	1.414	2.449	32	22.627	39.192	62	43.841	75.934
3	2.121	3.674	33	23.335	40.417	63	44.548	77.159
4	2.828	4.899	34	24.042	41.641	64	45.255	78.384
5	3.536	6.124	35	24.749	42.866	65	45.962	79.608
6	4.243	7.348	36	25.456	44.091	66	46.669	80.833
7	4.950	8.573	37	26.163	45.316	67	47.376	82.058
8	5.657	9.798	38	26.870	46.540	68	48.083	83.283
9	6.364	11.023	39	27.577	47.765	69	48.790	84.507
10	7.071	12.247	40	28.284	48.990	70	49.497	85.732
11	7.778	13.472	41	28.991	50.215	71	50.205	86.957
12	8.485	14.697	42	29.698	51.439	72	50.912	88.182
13	9.192	15.922	43	30.406	52.664	73	51.619	89.406
14	9.899	17.146	44	31.113	53.889	74	52.326	90.631
15	10.607	18.371	45	31.820	55.114	75	53.033	91.856
16	11.314	19.596	46	32.527	56.338	76	53.740	93.081
17	12.021	20.821	47	33.234	57.563	77	54.447	94.306
18	12.728	22.045	48	33.941	58.783	78	55.154	95.530
19	13.435	23.270	49	34.648	60.012	79	55.861	96.755
20	14.142	24.495	50	35.355	61.237	80	56.569	97.980
21	14.849	25.720	51	36.062	62.462	81	57.276	99.204
22	15.556	26.944	52	36.770	63.687	82	57.983	100.429
23	16.263	28.169	53	37.477	64.911	83	58.690	101.654
24	16.971	29.394	54	38.184	66.136	84	59.397	102.879
25	17.678	30.619	55	38.891	67.361	85	60.104	104.103
26	18.385	31.843	56	39.598	68.586	86	60.811	105.328
27	19.092	33.068	57	40.305	69.810	87	61.518	106.553
28	19.799	34.293	58	41.012	71.035	88	62.225	107.778
29	20.506	35.518	59	41.719	72.260	89	62.933	109.002
30	21.213	36.742	60	42.426	73.485	90	63.640	110.227

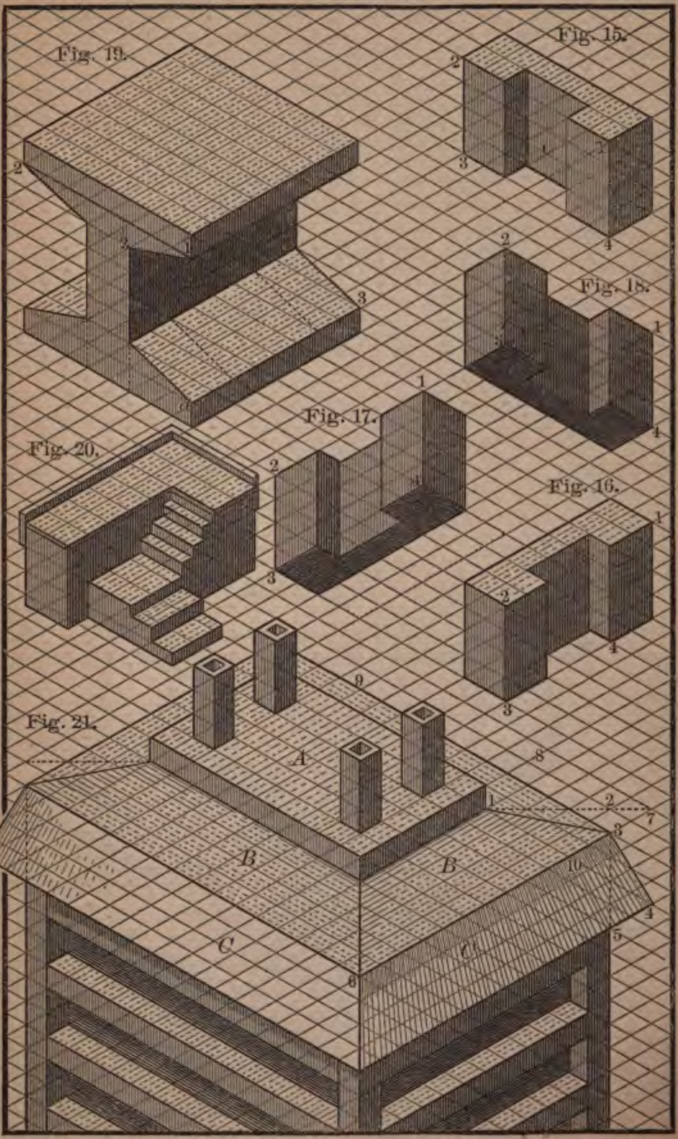
Scale of two inches to a space. Pl. I.



Scale of one foot to a space. Pl. II.



Scale of two feet to a space. Pl. III.



Scale of one foot to a space.

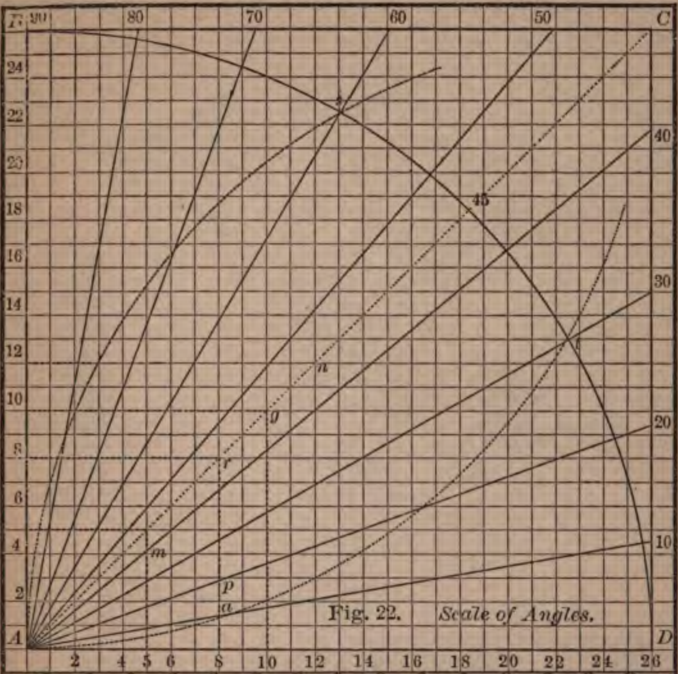


Fig. 22. *Scale of Angles.*

Fig. 23.

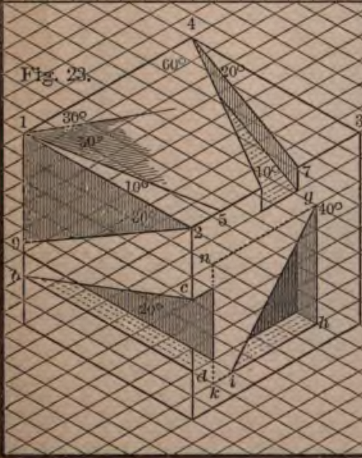


Fig. 25.

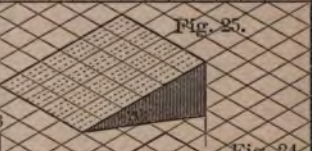
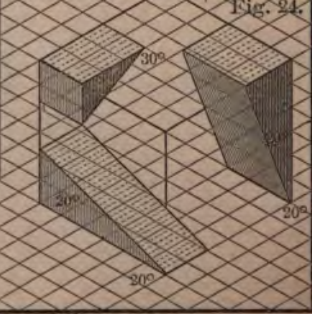
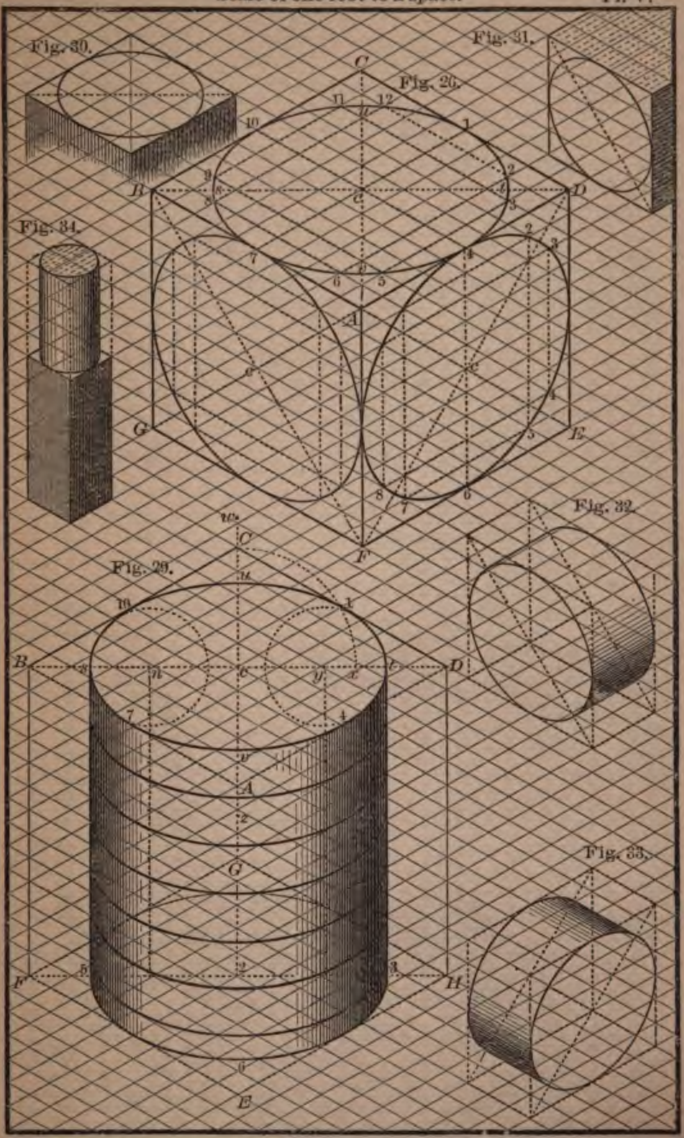


Fig. 24.



Scale of one foot to a space. Pl. V.



Scale of one foot to a space. Pl. VI.

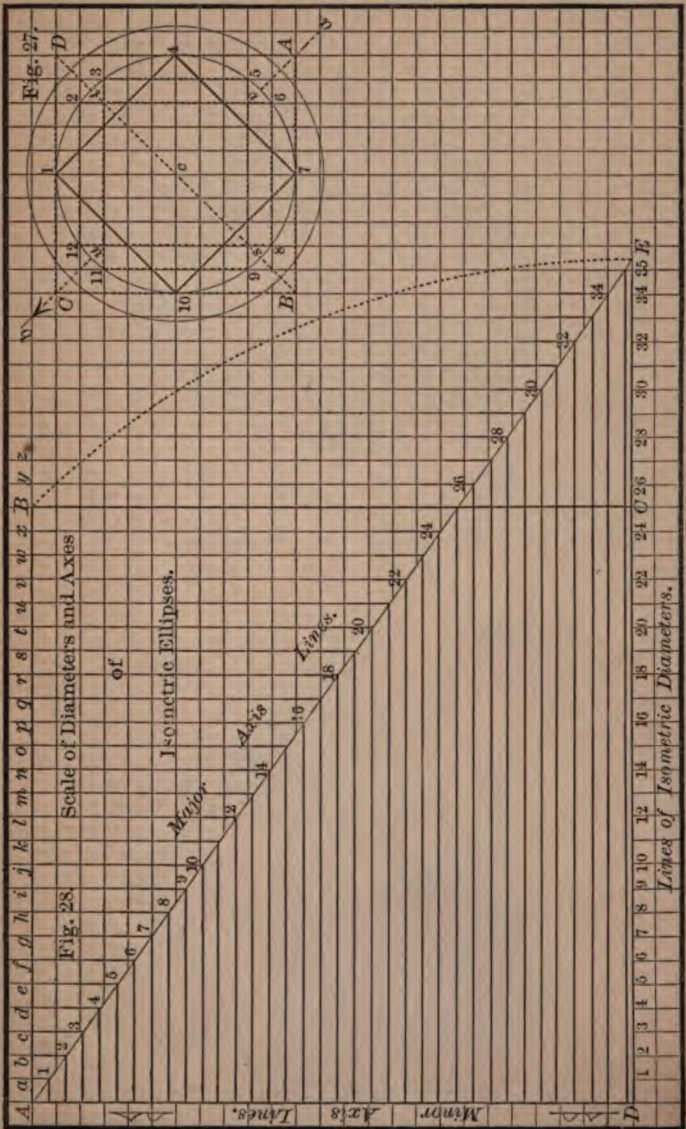


Fig. 27.

Fig. 28.

Scale of Diameters and Axes of Isometric Ellipses.

A a b c d e f g h i j k l m n o p q r s t u v w x B y z
D
A
C
B
c
1 2 3 4 5 6 7 8 9 10 11 12
x
w
Major Axis Lines.
Minor Axis Lines.
Lines of Isometric Diameters.
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24 26 28 30 32 34
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24 C 26 28 30 32 34 35 E
D

K

Scale of one foot to a space. Pl. VII.

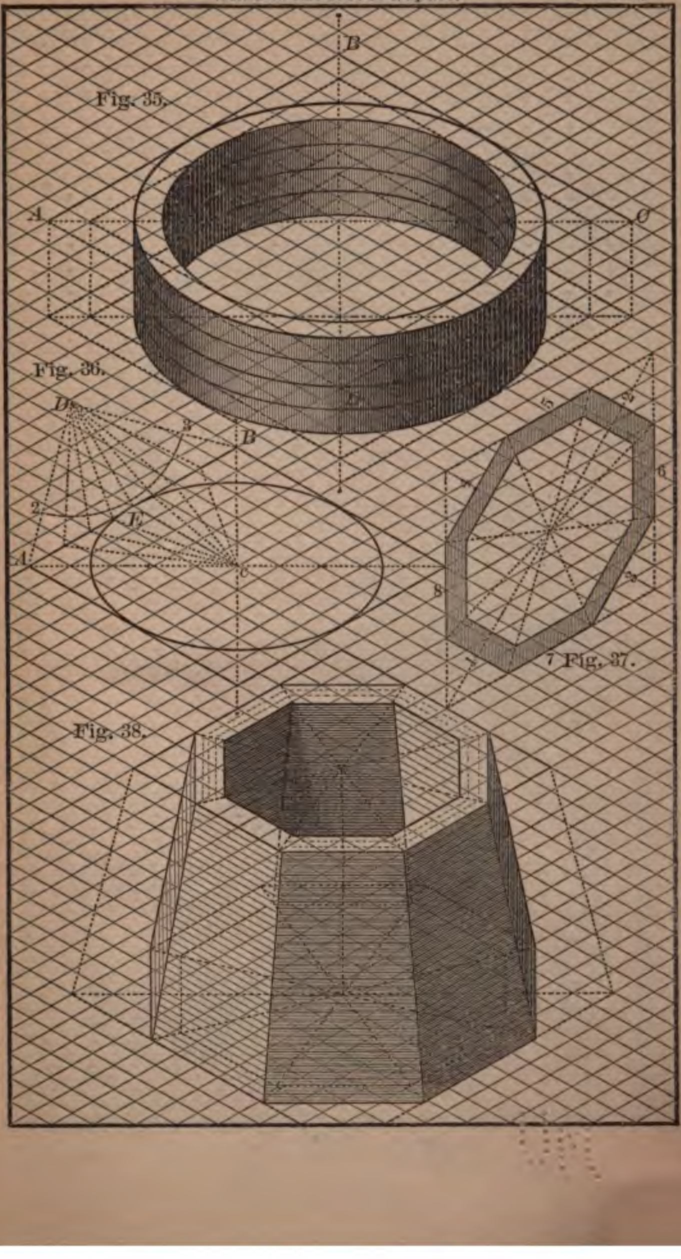


Fig. 35.

Fig. 36.

Fig. 37.

Fig. 38.

Scale of one foot to a space. Pl. IV.

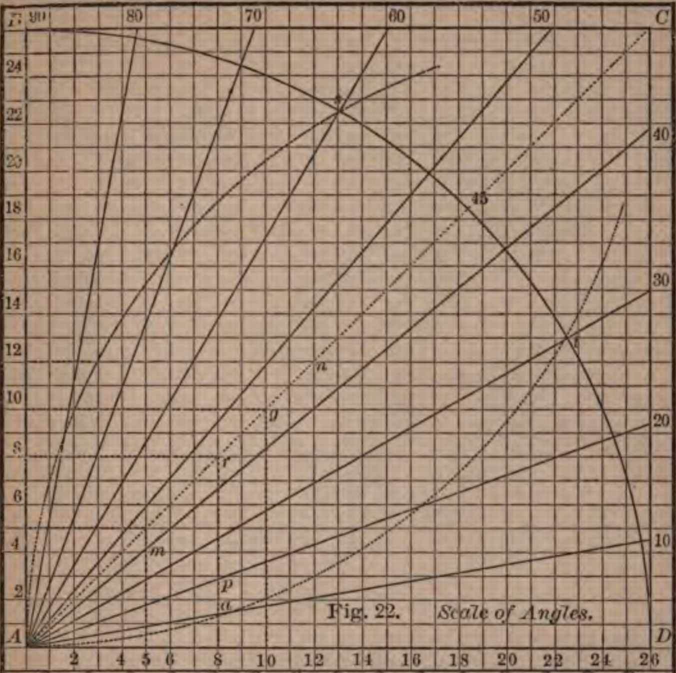


Fig. 22. *Scale of Angles.*

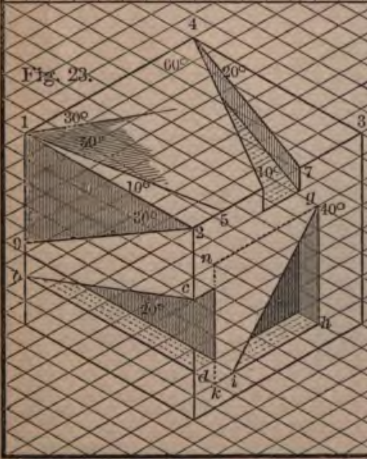


Fig. 23.

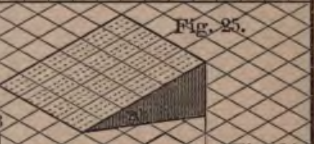


Fig. 25.

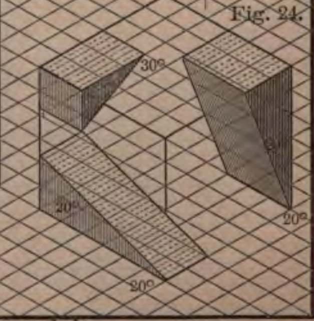
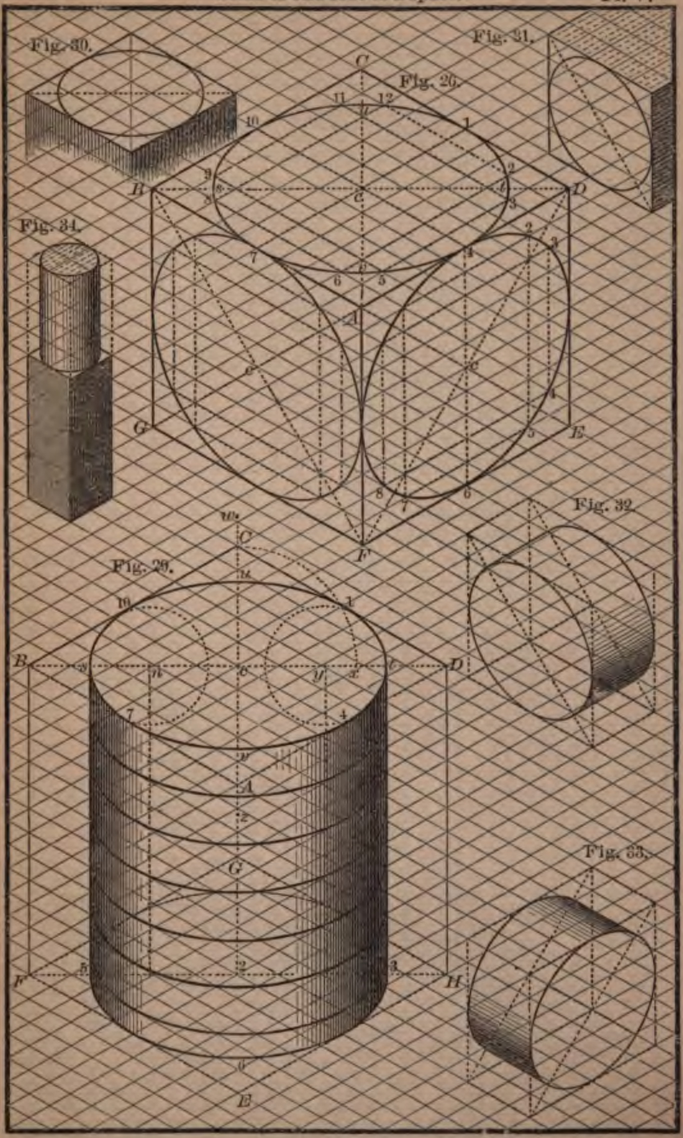
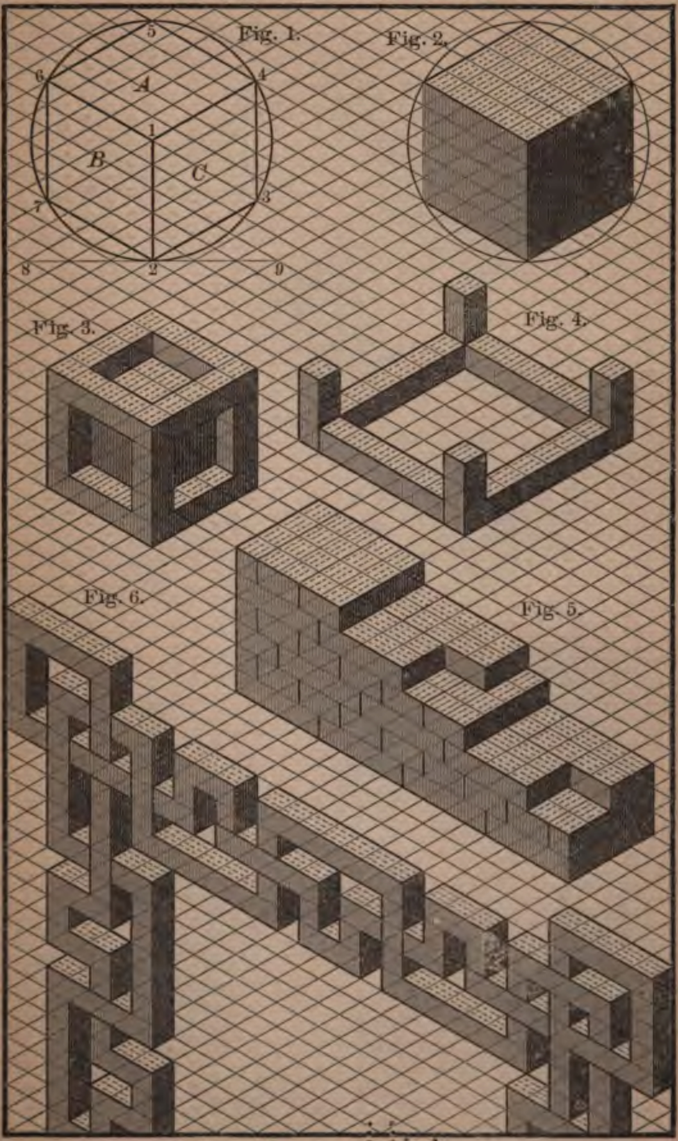


Fig. 24.

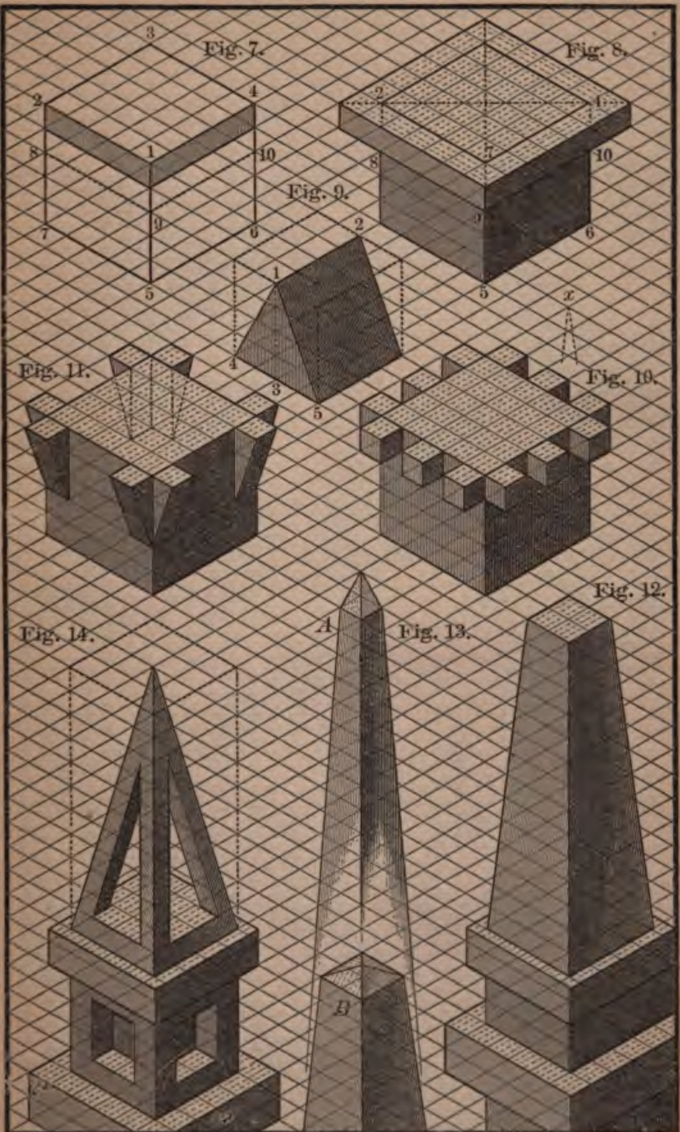
Scale of one foot to a space. Pl. V.



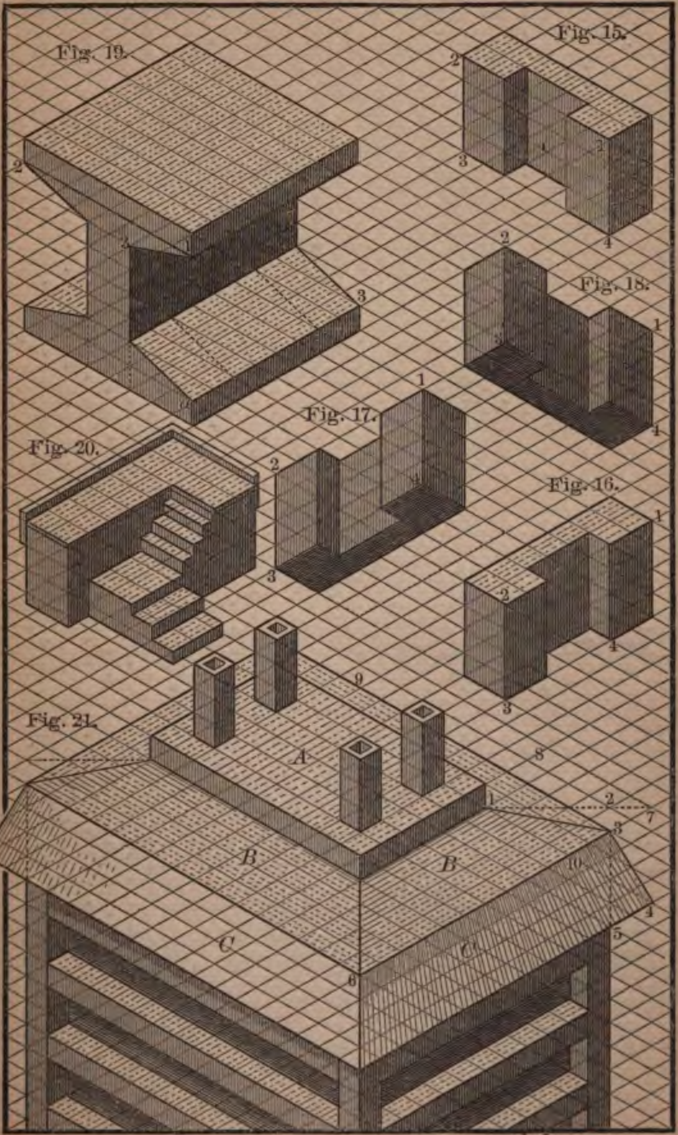
Scale of two inches to a space. Pl. I.



Scale of one foot to a space. Pl. II.



Scale of two feet to a space.



Scale of one foot to a space. Pl. IV.

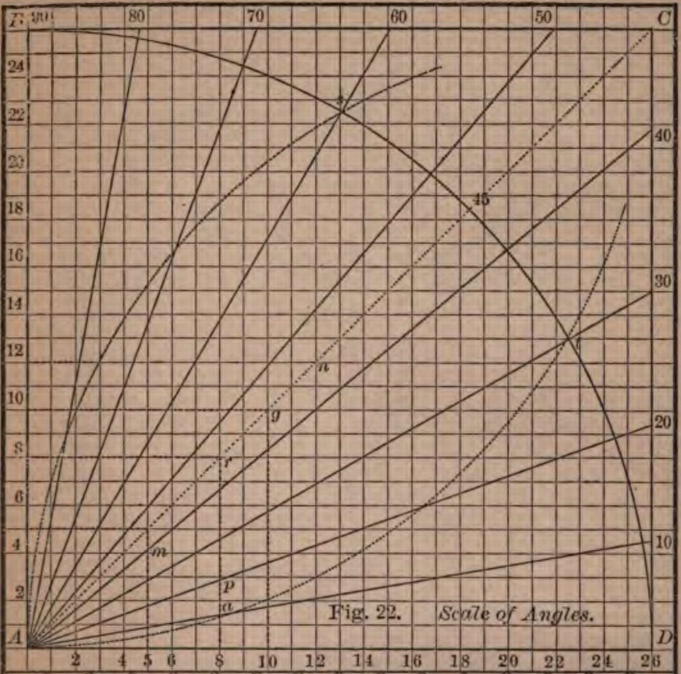


Fig. 22. *Scale of Angles.*

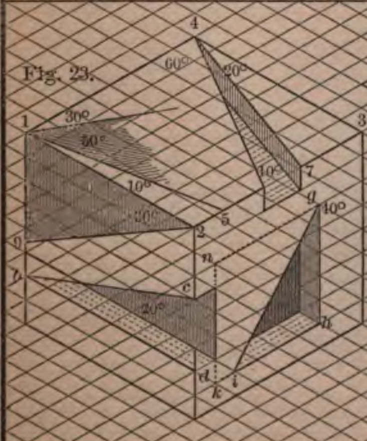


Fig. 23.

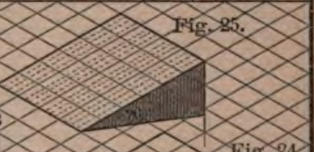


Fig. 25.

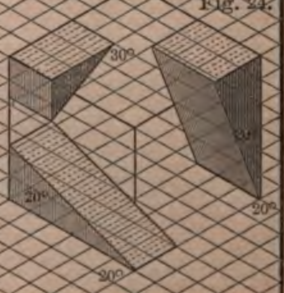
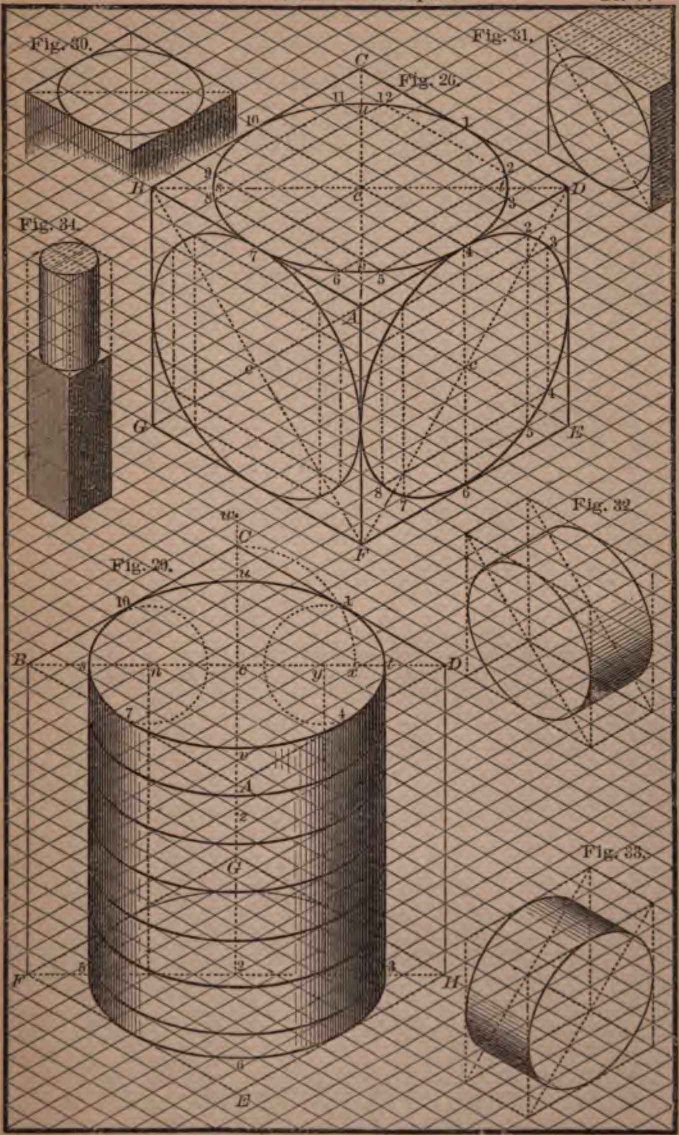


Fig. 24.

Scale of one foot to a space. Pl. V.



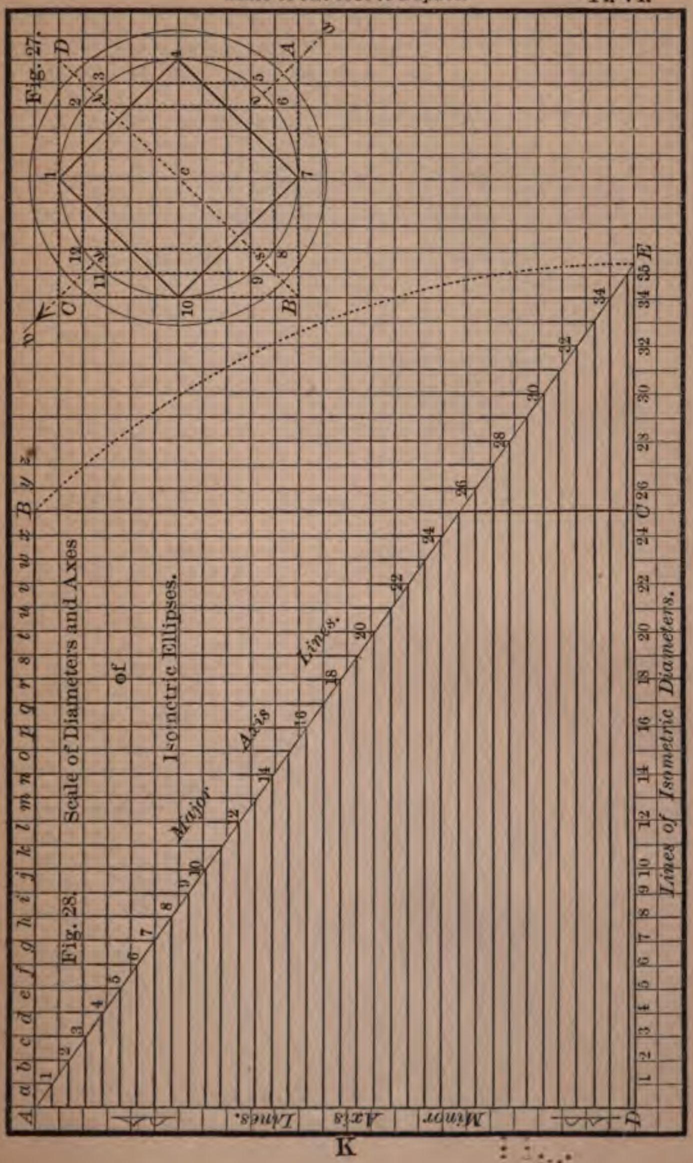
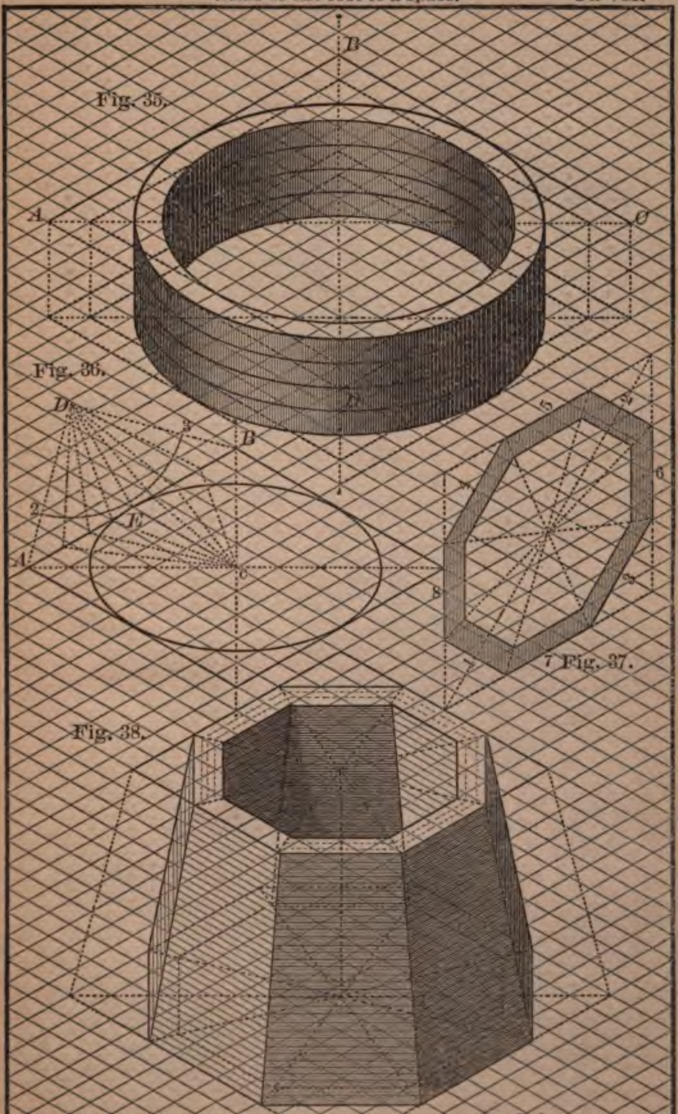


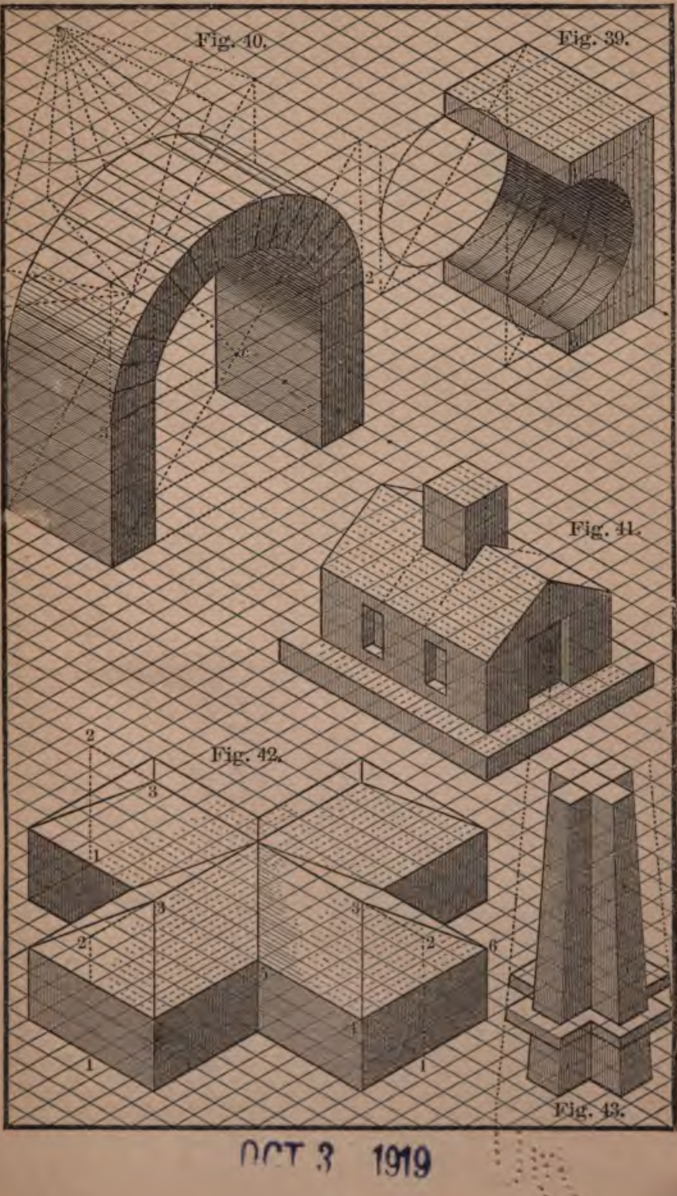
Fig. 27.

Fig. 28.

Scale of Diameters and Axes
of
Isometric Ellipses.
Major Axis Lines.
Minor Axis Lines.
Lines of Isometric Diameters.
A a b c d e f g h i j k l m n o p q r s t u v w x B y z
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24 26 28 30 32 34
C D E K
A B C D c w x y z
1 2 3 4 5 6 7 8 9 10 11 12

Scale of one foot to a space. Pl. VII.





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